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HERMANN CARL VOGEL.

HECTOR MACPHERSON, JR.

FOR POPULAR ASTRONOMY.

One of the greatest of modern astronomers has passed away. Dr. Vogel is dead. The death of the great German astronomer is one of the most serious losses which has befallen astronomy for a considerable time, for Dr. Vogel stood in the very front rank of present day astronomers.

Herman Carl Vogel was born on April 3, 1842, in Leipzig, where his father Dr. Carl Vogel was a well-known schoolmaster. In 1863 he entered the University of his native town, where he took his degree in 1867. Meanwhile he had become devoted to astronomy and in 1865, while still a student, he was appointed assistant in the Leipzig Observatory, his interest in the science being due to his acquaintance with Zöllner. His first work at Leipzig was in practical astronomy, but in 1869 he took up the spectroscopic side of the science, assisting Zöllner in his observations of the solar prominences. In 1870 he was appointed director of a private observatory at Bothkamp, in Holstein, where he remained for four years. Into these four years were crowded a quantity of excellent work which at once made the name of Vogel famous in the astronomical world.

In 1874 Vogel published his treatise "Spectra der Planeten" in which he summed up his work on the planetary spectra. He suspected the presence of atmospheric lines in the spectrum of Mercury, but in that of Venus he could detect only the slightest difference from the Sun. In Mars he detected distinct lines of aqueous vapor, a conclusion previously reached by Sir William Huggins and confirmed by Dr. Vogel himself many years later. He also examined the spectra of Jupiter, Saturn, and their satellites and in the spectra of the satellites of Jupiter, he noticed strong bands, indicating the existence of atmospheric envelopes. At Bothkamp Vogel made telescopic observations of the planets, especially Venus, while he made visual measures of the radial motions of the stars, the line of research in which he made his greatest discoveries. It soon became apparent, however, that

satisfactory and reliable measures could only be made by the aid of photography. In 1874 Dr. Vogel left Bothkamp to accept a position which he had been offered in the new Astrophysical Observatory which the German Government established at Potsdam in that year; and in 1882 he became director of that institution, where he gathered round him a number of observers of great ability, Spörer, Scheiner, Müller, Kempf and others. In 1883, assisted by Dr. Müller, Dr. Vogel published the first spectroscopic star catalogue, containing details of the spectra of 4051 stars to the seventh magnitude.

At the Astrophysical Observatory in 1887, Dr. Vogel assisted by Dr. Scheiner commenced his photographic measurements of the radial motions of the stars. He photographed the spectra of fifty-one stars bright enough for observation with a 12-inch refractor, and measured the photographs microscopically. The results of the observations were published in 1892. Of these fifty-one stars, the swiftest proved to be Aldebaran, with a motion of recession of about thirty miles a second. This motion proved exceptional, the average speed in the line of sight being ascertained to be ten miles a second.

In the course of these observations, Dr. Vogel made his greatest discovery—the detection of spectroscopic binary stars. In 1888 and 1889 he tested spectroscopically the theory that the variations of Algol were caused by its eclipse by a dark satellite, and placed it in the region of actual fact. He found that before each minimum Algol was retreating from our system, while on recovering its brightness, it gave signs of approach. Working on the assumption that the density of both stars was the same, he reached the following interesting conclusions that Algol is a globe about one and a half millions of miles in diameter, and that the satellite is about the size of the Sun: the centers of the two stars being separated by about 3,230,000 miles.

In the following year, 1890, a more surprising discovery was announced from Potsdam. By the displacements of the lines in the spectrum of Spica, Dr. Vogel discovered that the bright star was also a spectroscopic binary, both stars revolving round their center of gravity in about four days. Spica, therefore is a star similar to Algol, only the plane of the orbit does not lie in our line of sight and it escapes eclipse. These investigations were the direct confirmation of the idea expressed by Bessel in 1844 regarding the "astronomy of the invisible."

Perhaps, however, Vogel's name is best known through his classification of the stars, propounded in 1874 and revised in

1895. The classification is a development of that of Secchi, but Vogel approached the question from another point of view, believing that a rational scheme classification "can only be arrived at by proceeding from the standpoint that the phase of development of the particular body is in general mirrored in its spectrum."

In "A Century's Progress in Astronomy", the writer has described the classification as follows: "Vogel divides Secchi's first type into three classes. In the first class, designated Ia—represented by Sirius and Vega—the metallic lines are very faint and fine and the hydrogen lines conspicuous. In Ib no hydrogen lines are visible, while in Ic the hydrogen lines are bright. This class includes the gaseous stars. In 1895, after the recognition of helium in the stars by his assistant, Scheiner, Vogel separated the stars of class Ib from the first type altogether. These stars are sometimes designated as Type 0, and sometimes as helium stars and Orion stars, as the majority of the stars in Orion are of that type. The solar type is divided into two classes, IIa being represented by the Sun, Capella and other well-known stars, while IIb includes the Wolf-Rayet stars. Secchi's third and fourth types are both classified by Vogel as of the third type."

In Dr. Vogel's opinion, Orion and Sirian stars are the youngest orbs. He believed that solar stars have wasted much of their store of radiation, while in his own words, red stars are "effete suns, hastening rapidly down the road to final extinction." Stars of his class IIIb, or Secchi's fourth type are in his opinion, also dying stars, both types representing alternative roads for stars of the solar type in their decline. This view is supported by Professor Dunér and Professor Hale. Dr. Vogel's classification and scheme of evolution is generally accepted, and it will long be remembered as a masterly effort to unravel the secrets of the universe. His scheme of evolution is distinctly supplementary to the nebular theory.

Dr. Vogel's eminence as an astronomer was recognized all over the scientific world. Member of many scientific societies, he received the Valz Prize of the Paris Academy of Sciences in 1891 and the Gold Medal of the Royal Astronomical Society of London in 1893. In his native country, too, his services to science were fully recognized. In 1895 he received the Prussian Order of Merit, and in 1899 he became Privy Councillor of Germany.

In this article we have mentioned only the chief investigations and discoveries in Vogel's busy life—a life of ceaseless activity. His devotion to astronomy increased, rather than diminished with the years. In 1905, in a letter to the writer he mentioned

that he was at that time "overburdened with work." Some time ago, his health began to fail. A malady which afflicted him about seven years ago recurred in the present year, and in the latter end of July he grew gradually worse. He died at Potsdam on August 14, 1907, in his sixty-sixth year, and the funeral service of one who had done so much for astronomy and who had been the shining light of the Observatory at Potsdam, was fittingly held in the dome of the great telescope with which he worked so skilfully and so well. His death leaves a blank in astronomy which cannot well be filled.

Johnsburn, Balerno,
Midlothian, Scotland.

LEO DE BALL'S REFRACTION TABLES.*

[Review by L. Courvoisier in V. J. S. der Art. Gesell. 42 Jahrgang, Erstes Heft, p. 74. Translated by Milton Updegraff.]

In the new refraction tables of de Ball, there is made for the first time an attempt to supplement the foundation of a modern theory (Radau, "Essai sur les réfractions astronomiques," Annales de l'Observatoire de Paris t. xix) by the deduction of a modern refraction constant. This needs no defense provided that care is taken to make due allowance, in the light of modern developments, for the influence of the humidity of the atmosphere in bending the rays of light and of the late advances in our knowledge of the constitution of the atmosphere. Tables depending on such a theory—and the well-known tables of Radau himself as well as those under consideration belong to this class—will give the refraction with a high degree of approximation to the truth. In regard to the necessity of an improvement of the until now generally used refraction constant of Bessel, there exists nevertheless a doubt which can be removed only by reflection upon the fact that determinations of this constant made in favorable observation rooms and with reliable temperature† determinations have tended not only towards smaller but toward very considerably smaller values.

We venture here to give place to some figures. The fundamental constant of Bessel's Tabulæ Regiomontanæ amounts to 60″.44, while de Ball adopts a value of only 60″.15 deduced by Bauschingen from researches in Greenwich, Pulkowa and Munich. The

* Leipzig, Engelmann, 1906, XIV and 17 pages.

† Uber die Art, wie Bessel sein Thermometer angebracht hat, siehe Nysén Publ. de l'Obs. Central Nicolas, Série II Vol. II p. (2).

reviewer ventures to add that his own determination, made in the apparently well ventilated observing room at Heidelberg with an unusually wide slit with the result $a = 60''.16$, completely confirms this adoption. Consequently the difference of the two table-constants is about $0''.3$, and it is easy to see that absolute measurements will be affected by its full value, and also that in differential observations the effect will not be negligible. For example at 60° zenith distance the error amounts to about $0''.5$, at 70°, $0''.8$ and at 80°, $1''.5$; the error of pole-height determinations resulting from absolute measures in mean latitudes would be about $0''.25$; the error of determinations of the obliquity of the ecliptic deduced from observations (in latitude 50°) of the altitudes of the Sun at the solstices about $0''.4$ and so on. If we take moreover at a northern observatory for example, the determination of the places of zodiacal stars with reference to fundamental stars it will only seldom be possible in case of the more southerly stars to so group the reference stars that they shall be arranged symmetrically with reference to the zone of observation, and in this way errors of $0''.5$ and more will arise.

If then the question arises as to what refraction constant should be used in a certain observatory, the answer depends on whether or not there exists an independent determination of the refraction for that place. In the first case, when the highest accuracy is to be attained, the rule given by Egon V. Oppolzer should be followed which says* that under these circumstances, in reducing the observations the constant found must be used together with readings of the thermometer which was used in determining the constant. In this way, under normal atmospheric conditions, the safest representation of the observations will be attained, for it can no longer be doubted that the difference between the constants obtained (which are especially evident in case of the old meridian rooms)arises almost exclusively from the influence of local factors, especially from the greater or less uncertainty in the determinations of the true air-temperature,† and from the form of the air layers in the observing room which disturb the normal refraction. With reference to this last point it is possible according to the conception of the writer, to speak of an exact constant of refraction only when it pertains to the free atmosphere where in accordance with the theoretical

* Valentiner, Handwörterbuch der Astronomie Bd. III² p. 600.

† Ueber hypothetische Temperaturefehler bei den Refraktionsbestimmungen siehe ebenda p. 599.

considerations, the temperature of the last refracting layer before the object glass is determinative.

Conditions analogous to those in the free air will naturally exist in the meridian room when there the air layers of equal density can be regarded as running parallel with those of the outside air. According to the experience of the reviewer, this is in fact * the condition in the Heidelberg observing room and presumably will be found to be nearly the case in most new observing rooms.

From the agreement of the Heidelberg constant (which was determined with the most thorough consideration of the room-refraction) with that of the table of the author the writer ventures, on that account, to draw the conclusion that this last corresponds very nearly to the true refraction constant pertaining to the free air. The observations should consequently be made in a room with a wide meridian-slit and a good temperature equalization, for then, although no especially determined refraction constant exists, all foresight toward securing the best results is exercised by the use of de Ball's tables and the inside temperature.

After this general discussion, which the reviewer considers necessary for the proper exposition of the undertaking of de Ball a short explanation of the arrangement of the tables will be attempted.

The form of presentation of the refractions and the method of their computation which (with the exception of the experimentally introduced small auxiliary table No. 3) is logarithmic throughout, may be described as the result of careful experiments and studies which the author has exhibited in various articles in the Astronomische Nachrichten. (Here may be mentioned the articles: "Ueber den Einfluss der Refraktion auf die Distanz zweier Sterne," Bd. 164, p. 373; "Neue Refraktionstafeln," Bd. 166, p. 353; "Eine zweite neue Form von Refraktionstafeln" und "Formeln und Tafeln für die Refraktion in Positionswinkel und Distanz", Bd. 168, p. 245: "Ueber den Einfluss des Dampfdruchs auf die Refraktion," Bd. 169, p. 179; "Ueber eine Tafel zur logarithmischen Berechnung der Refraktion," Bd. 169, p. 209; "Zur Berechnung der Refraktion in Positionswinkel und Distanz," Bd. 170 p. 373).

With reference to the logarithmic computation of the refraction it is next to be remarked that it has been especially adopted not alone through the use of Bessel's tables in astronomical

¶ Veroffentlichungen der grossh. Sternwarte, Heidelberg Bd. III p. 207.

practice, but that it has also the advantage over the direct numerical computation, at least when a table—as is the case with that under consideration—is completely uniform for all arguments. The direct computation after the manner of the above-mentioned Table 3 is indeed very practicable for small zenith distances but at great zenith distances such tables need to be unduly expanded in order to make the interpolation convenient and they thereby lose their synoptic character.

The reviewer may further designate as an especial advantage of these tables that the fourth decimal place of the logarithms has been fixed as the extreme limit of accuracy. The author remarks anew in the introduction that the accidental error of the temperature determination of the air makes illusory all accuracy gained by carrying the computation in each case beyond the fourth place inasmuch as these places in the logarithm of the air density and consequently also in the refraction are uncertain. There corresponds to a temperature-error of $\pm 0°.05$C., which without doubt always exists, an error on the average 0.0001 in the logarithm of the refraction.

The de Ball tables extend to 80° zenith distance which is in almost all cases sufficient. Beyond that limit the tables of Radau which are based on the same theory, but which on the other hand are computed with the old Bessel constant of the Tabulae Regiomontanae must be proportionately extended. As is of itself evident the refractions taken from those tables need, in order to be reduced to the new constant, to be multiplied by the ratio of the two constants. The form which de Ball uses for the representation of the refraction arises from the following considerations. For zenith distances smaller than 84°, the refraction can be developed into the series:

$$\text{Refraction} = A_0 \tan z - A_1 \tan^3 z + A_2 \tan^5 z \mp \ldots\ldots,$$

wherein the coefficients A_0, A_1, A_2 etc., are functions of the refraction constant α and of the meteorological conditions. For example and in particular, according to the Radau theory,

$$A_0 = \alpha''\left(1+\tfrac{3}{2}\alpha - \frac{l_0}{R}\right)$$

in which

$$\frac{l_0}{R} = \frac{7.993}{6566}(1+0.003663.t),$$

$$\alpha = \frac{c\rho}{1+2c\rho}$$

and α'' is the refraction in seconds of arc, t the temperature, ρ the density of the air and c an absolute constant. Further, we have the expression:

$$\rho = \frac{\beta}{760} \cdot \frac{1-0.000162.t}{1+0.003663.t}$$

in which β is the barometer reading corrected for height above sea level, geographical latitude and humidity.

If R is the refraction for a given zenith distance, and with the air density ρ and the air temperature t, R_0 the mean refraction, that is the refraction for $\rho=1$ and $t=0°$ at the same zenith distance, then there follows from the expression for α with close approximation in consideration of the circumstance that c is a very small constant,

$$\log R = \log R_0 + \log \rho.$$

Since however, as is seen—and this is likewise true of the other coefficients of the series—A_0 involves ρ in the denominator and also t explicitly, the rigorous formula for the refraction runs as follows:

$$\log R = \log R_0 + \log \rho + \text{Temp. Cor.} + \text{Density Cor.}$$

This expression is especially convenient, as direct addition is used, the correction terms first become appreciable at great zenith distances and are generally very small.

The author calls these additional terms "corrections to $\log R_0$." The reviewer may be permitted to remark here that this designation, while entirely intelligible in the connection, is not however unobjectionable, as R_0 has been defined throughout as the value of the refraction for $\rho=1$ and $t=0$, and therefore cannot be dependent on these quantities. This is also correctly expressed in Formula (1) of the Introduction:

$$\log \frac{R}{\rho} = \log R_0 + \left(\frac{d}{\delta t} \log \frac{R}{\rho}\right)_{\rho=1,\ t=0} . t + \left(\frac{\delta}{\delta t} \log \frac{R}{\rho}\right)_{\rho=1,\ t=0} . (\rho-1)$$

which the author uses in part for the deduction of R. In fact they are corrections to the approximate refraction,

$$\log R = \log R_0 + \log \rho,$$

because the multiplication of the mean refraction by ρ alone does not, as is shown above, rigorously suffice. If we further write,

$$\frac{\beta}{760} = B \text{ and } \frac{1-0.000162.t}{1+0.003663.t} = T,$$

we get,

$$\log \rho = \log B + \log T$$

and obtain finally as the complete formula for the refraction,

$$\log R = \log R_0 + \log B + \log T + \text{Temp. Cor.} + \text{Density Cor.}$$

Corresponding to this expression the new refraction tables are arranged as follows. In the first place, with the help of two small tables computed once for all for the place of observation, (See the remarks of the author in the explanation of the tables) the barometer readings are reduced in a convenient manner to the value β. When the humidity has received no special consideration a mean humidity of 6mm. is used, but in many cases an approximate value of the humidity is sufficient.
Then follow:

Table 1, with the argument $\beta = 690$ mm. to 790 mm. from 0.1 to 0.1 mm. for log B.

Table 2, with argument $t = -30°$ to $+38°$ C from 0°.1 to 0°.1, for log T.

Table 3, with argument z (apparent zenith distance) $= 0°\ 0'$ to $0°\ 25'$, from $1'$ to $1'$ and log $\rho = 9.90 - 10$ to 0.07, from 0.0 to 0.01, giving directly the numerical value of the refraction.

Table 4, with argument $z = 0°$ to $80°$, from $1'$ to $1'$ for the log R_0.

Table 5, with the argument $z = 40°$, $50°$ to $80°$ from $1°$ to $1°$,, and $t = -38°$ to $+38°$ C, from $1°$ to $1°$, for the temperature correction in units of the fourth decimal place.

Table 6, with the argument $z = 65°$ to $80°$ from $1°$ to $1°$, and log $\rho = 9.90 - 10$ to 0.07 from 0.01 to 0.01, for the density correction in units of the fourth decimal place.

The refractions were computed from $z = 0°$ to $75°$ for various temperatures and densities, directly by means of the development in series; between $z = 75°$ to $80°$ the above-mentioned differential formula (1) came into use. For the greatest zenith distances, the term in $\tan^{13} z$ in the series was used in the computations. The accuracy of the table-values were checked by the author by differences and also by comparison with the tables of Radau.

With reference to Table 6, it may be remarked that the sign of the correction does not correspond to what one would expect from the expression for the first coefficient A_0, although the result is caused by the omission of the higher terms. As one is easily convinced, the representation of the refraction in these tables is at least as convenient for computation as is the case in the tables of Bessel, which indeed also depend on the same principle bringing in of the density of the air as a factor. By way of comparison, the formula of Bessel may be given. Bessel writes:

$$\log R = \log \alpha \tan z + A\,(\log B + \log T) + \lambda\,\gamma.$$

(An explanation of the notation is unnecessary since it is familiar to every astronomer,)

The slight difference between the two methods is that in case of de Ball's the barometer readings are corrected for temperature of the quick silver etc., before being used in the table, while in case of Bessel's, this is effected in a certain measure by the addition of log T. Arithmetically this comes to the same thing. Aside from this Bessel applies the small corrections to the approximate refraction in the form of two factors A and λ which in the opinion of the reviewer, especially in view of the necessary separation of the influence of air pressure from that of temperature, is decidedly less convenient than the simple addition of two small quantities to log R_0 as in the de Ball formula.

In order to make his refraction tables complete, the author extends them to the differential astronomical refraction. Tables 7 to 9 serve for the computation of the refraction in position angle and distance as is needed in heliometer observations where the distances are great. The author has deduced the necessary expressions for that purpose in A.N. Bd. 168 and 170, and they are again collected in the explanation of the tables. The parameters f, g, α' which occur in the formulae are functions of the zenith distance as well as of the density and the temperature of the air. For $\rho = 1$ and $t = 0$ they become f_0, g_0 and α_0' and there are—

Table 7, with argument ζ (the true zenith distance), from 0° to 75°, for log f_0, log g_0, and log α'_0.

Table 8, analogue of Table 6, argument ζ for log ρ, the density correction.

Table 9, analogue of Table 5, arguments ρ and t for the temperature correction to the approximate refraction in position angle and distance.

For micrometer observations there is Table 10 which gives with the argument ζ from 0° to 75°, the value of log α'' expressed in parts of the radius which are functions of ζ, f_0 and α_0'. The sum log α_0' + log ρ there corresponds to the quantity designated as κ by Bessel. The correction terms may here be neglected.

For the various refraction formulae reference is made to the work of E. Becker "Mikrometer und Mikrometer messungen." In the opinion of the reviewer it would have been better if the principal formulae had been incorporated in the explanation of the tables since in the monograph of Becker they are somewhat scattered.

Finally we consider the last table, 11, the "Photographie Refraktion". If the expressions for the refraction for visual observations are $\kappa \tan z$ and $\kappa' \tan z$, then for photographic work the corresponding values are $1.0155\ \kappa \tan z$ and $1.0155\ \kappa' \tan z$ respectively.

We then have:

$$\log (1.0155\ \kappa \sin 1'') = \log A + \log \rho$$

$$\log (1.0155\ \kappa' \sin 1'') = \log A' + \log \rho,$$

and Table 11 gives with arguments z and ζ, from 0° to 60°, the values of $\log A$ and $\log A'$ respectively.

Also in the tables for the differential refraction stress is laid on the introduction of the new constant and the air density as a factor in the formulae.

The author has given the introduction and the explanation of his refraction tables and also the titles of the separate tables in both the German and French languages. The outward form of the volume and of the tables is very handy and convenient, the print is clear and distinct, so that in this respect—aside from its other merits—the work can be most confidently recommended to experts.

ON THE DISTORTIONS OF PHOTOGRAPHIC FILMS ON GLASS.*

SEBASTIAN ALBRECHT.

Introduction.

In various lines of astronomical research depending upon photographic plates discrepancies of a considerable magnitude occasionally appeared, which seemed attributable to no definite cause. On the star-photographs taken with the Crossley reflector, these occasional discrepancies, which seemed to be more or less accidental, usually amounted to a few tenths of a second of arc, and very rarely to as much as a second of arc, which is equivalent to a linear distance of about 0.001 inch (0.025mm.). Even though discrepancies are the exception rather than the rule, and discrepancies of the magnitude referred to above are extremely rare, nevertheless they cause considerable annoyance when extreme accuracy is desired, for the error of measurement need not much

* From second section of thesis in partial fulfillment of requirements for the degree of Doctor of Philosophy in the University of California.

exceed 0.001 mm. It seemed highly desirable to locate definitely, if possible, the cause of the difficulty. In the case of the Crossley star-photographs it seemed to me for a time as though the cause must be sought for in the large mirror of the telescope. Another alternative was the study of the photographic film itself. Accordingly, in the winter of 1904, at the suggestion of Director Campbell and Dr. Perrine, the writer undertook an investigation of the distortions of the gelatine film.

The principal previous investigations on the distortions of the gelatine film were made by Scheiner, Loewy, Bergstrand, and Ludendorff. Scheiner* at first believed he had found a contraction in one coördinate and a dilation in the other, and assumed that this distortion was progressive, *i. e.*, proportional to the distance measured. In 1897,† however, he says: "Weitere Erfahrungen haben indessen gezeigt, dass man wahrscheinlich die Verziehungen nicht der gemessenen Strecke proportional setzen darf, sondern dass sie ziemlich localer Natur sind und sich häufig schon auf sehr kurze Strecken hin nieder aufheben."

Loewy,‡ from a study of an *Eros* plate with multiple exposures, using three images of each of 82 stars, came to the conclusion that distortions of the film introduced an accidental error into the differences $x_n - x_m$ and $y_n - y_m$ which was represented by a probable error of 0″.06 (=0.001 mm. or 0.00004 inch).

Bergstrand‖ investigated two star-plates, and from his results drew the following conclusions: Except near the edges of the plate, the distortions are, in general, not common to large parts of the plates; the affected regions are in the nature of bands or strips, which are not greater than 5mm. and probably much smaller than this; these strips seem to have a tendency to be oftener parallel to one coördinate than to the other. The two plates studied by him seem to show a striking agreement both as to the amount and trend of the distortions, and he concludes therefore that the distortions cannot always be eliminated by the use of several plates.

Ludendorff§ investigated two of his star-plates and found that they showed large distortions which extend systematically over

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* *Zeitschrift für Instrumentenkunde*, XI, 394, 1891.

† Schiener, "*Photographie der Gestirne*," p. 119.

‡ *Sur La Precision des Coördinées des Astres. . . .*" Third Memoir, p. 83. In *Bulletin du Comité International Permanent pour l'Execution Photographique de la Carte du Ciel*, Vol. 3, 1902.

‖ *Öfversigt af K. Sv. Vet.-Akad. Förhandl.*, 1900, No. 2, p. 38.

§ *Astr. Nach.*, 162, 343, 1903.

a considerable portion of the plates. On both plates he found several neighboring reseau-lines to be curved, the convex side being directed towards the center on one of the plates, and away from the center on the other. In some cases he found the inclination of the reseau-lines to be somewhat changed. The largest relative displacement between two neighboring lines was 10μ. He states, however, that his endeavor was principally to find plates with strong distortions. It is well to quote some of the additional circumstances to which he calls attention. "Ganze Gruppen von Platten, welche an denselben Abend oder an naheliegenden Abenden aufgenommen wurden, weisen an demselben Randstriche Krűmmungen in demselben Sinne, aber von verschiedenen Betrage auf. Auch kommen mitten unter diesen Platten ganz normale vor."

"Auffällig bliebt indessen, dass diese Verzerrungen an Platten, welche aus derselben Zeit stammen, mit solcher Regelmässigkeit auftreten, bei Platten aus anderen Zeiten garnicht, und dass sie, wenigstens soweit meine Beobachtungen reichen, hauptsächlich einen bestimmten Strich (A 26) und dessen Nachbarstriche betreffen." He explains these facts in the following words: "Bei näherer Überlegung sieht mann indessen, dass es möglich ist, für beide Erscheinungen plausible Ursachen anzuführen. Da die Gitterkopien alle gleichartig in den Kasseten gelegen haben, so wird es sich ganz von selbst ergeben, dass sie sich auch bei allen photographischen Prozessen in derselben Lage befunden haben. Namentlich beim Trocknen, während dessen die Platten nahezu senkrecht standen, meist eine bestimmte Seite des Gitters die untere, horizontale gewesen sein. Eine nähere Betrachtung der nötigen Manipulationen macht es nicht unwarscheinlich, dass dies der Strich 26 gewesen ist." He also says that he found numerous cases of local distortions. As an example of these, he mentions plate No. 40, on which portions of two neighboring reseau-lines are bent in opposite directions.

From the above outline will be seen that our knowledge of the nature and amounts of the distortions was quite indefinite. The prevailing opinion in regard to the subject was well stated by Professor H. H. Turner* of Oxford, who is here quoted:" Even now it can scarcely be said that we know definitely the stage of refinement at which we must begin to expect irregular displacements of the images from distortion of the photographic film; but we have learned that they do not occur in a gross degree,

**Observatory*, XXVII, 396, 1904.

and that other apparatus must be improved before we need turn our attention seriously to errors arising from such a cause."

The more important features of the plan upon which my work was begun were investigations of the effects of (*a*) the position of the plate during the processes of washing and drying, (*b*) the rate of drying, (*c*) abrupt changes in the rate of drying during the process, (*d*) change in the position of the plate while drying, (*e*) hardener. Emulsions on plate-glass were also tried. Jewell's developer was used, and the plates were 3¼ by 4¼ inches (83×108 mm.) in size, the same as are used with the Crossley reflector.

Summary of Results.

1. For the size of the plates used (3¼ by 4¼ inches) it was found to be entirely indifferent whether the plate be vertical or horizontal during development, fixing, washing, and drying.

2. Within the range of the observations, hardener, the rate of drying, and changes in the rate of drying and in the position of the plate during the process of drying introduced no general distortions of the gelatine film.

3. Local distortions were found on artificial star plates and on spectrograms. These distortions were confined in each case to an area equal to a small fraction of a square millimeter. The largest lateral displacement found at any point in the distorted area was 0.02 mm., while the great majority were less than one-fourth of this amount. Some of these displacements are several times as large as the errors of measurement, and their possible effects must be taken into account where great accuracy is desired.

4. These distortions seem to be principally of two different kinds: one was due to an actual movement of a minute portion of the film, the other was an apparent shift of the image due to the peculiar arrangement of the silver grains or to local differences in the sensitiveness of the film.

5. The results obtained from one plate-glass showed no advantages of the plate-glass over the ordinary commercial plates in the matter of distortions of the film.

6. If the results obtained in this investigation for small plates be found to apply with equal force to larger plates, it will follow that the assumption which is the basis for the use of the reseau is not well founded. The assumptions involved, briefly stated, are as follows: First, general distortions exist: second, they differ in different parts of the plate: third, they may be assumed to be linear within the squares of the reseau, *i.e.*, over a stretch of 5mm. or more. The supposed advantages of the reseau over

the method of referring all the measures to a common center rest entirely upon the validity of these three assumptions. If the reseau can be dispensed with, there will be a saving of the labor involved in making the large number of settings on the reseau-lines and in the reductions of the measurements.

Throughout these investigations on photographic distortions I had the valued advice and assistance of Dr. Perrine, who had long been interested in the problem, and it is a pleasure to acknowledge my indebtedness to him. It should also be said that fully half of the measures of the first series were made by him.

May, 1907.

EXTRACTS FROM PRESIDENTIAL ADDRESS.*

SIR DAVID GILL.

The Solar Parallax.

Much progress has been made in the exact measurement of the great fundamental unit of astronomy—the solar parallax.

Early in 1877 I ventured to predict† that we should not arrive at any certainty as to the true value of the solar parallax from observations of transits of Venus, but that the modern heliometer applied to the measurement of angular distances between stars and the star-like images of minor planets would yield results of far higher precision.

The results of the observations of the minor planets Iris, Victoria and Sappho at their favorable oppositions in the years 1888 and 1889, which were made with the coöperation of the chief heliometer and meridian observatories, fully justified this prediction‡. The Sun's distance is now almost certainly known within one-thousandth part of its amount. The same series of observations also yielded a very reliable determination of the mass of the Moon.

The more recently discovered planet Eros, which in 1900 approached the Earth within one-third of the mean distance of the Sun, afforded a most unexpected and welcome opportunity for redetermining the solar parallax—an opportunity which was largely taken advantage of by the principal observatories of the northern hemisphere. Unfortunately the high northern declination of the planet prevented its observation at the Cape and

* Delivered at the meeting of the British Association, July 31, 1907.

† "The Determination of the Solar Parallax," *The Observatory*, vol. i. p. 280.

‡ 'Annals of the Cape Observatory,' vol. vi, part 6, p. 29.

other southern observatories. So far as the results have been reduced and published* they give an almost exact accordance with the value of the solar parallax derived from the heliometer observations of the minor planets, Iris, Victoria, and Sappho, in 1888 and 1889.

But in 1931 Eros will approach the Earth within one-sixth part of the Sun's mean distance, and the fault will rest with astronomers of that day if they do not succeed in determining the solar parallax within one ten-thousandth part of its amount.

To some of us who struggled so hard to arrive at a tenth part of this accuracy under the less favorable geometrical conditions that were available before the discovery of Eros, how enviable seems the opportunity!

And yet, if we come to think of it rightly, the true opportunity and the chief responsibility is ours, for *now* and not twenty years hence is the time to begin our preparation; *now* is the time to study the origin of those systematic errors which undoubtedly attach to some of our photographic processes; and then we ought to construct telescopes specially designed for the work. These telescopes should be applied to the charting of the stars near the path which Eros will describe at its opposition in 1931, and the resulting star-coördinates derived from the plates photographed by the different telescopes should be rigorously intercompared. Then, if all the telescopes give identical results for the star-places, we can be certain that they will record without systematic error the position of Eros. If they do not give identical results, the source of errors must be traced.

The planet will describe such a long path in the sky during the opposition of 1931 that it is already time to begin the meridian observations which are necessary to determine the places of the stars that are to be used for determining the constant of the plates. It is desirable, therefore, that some agreement should be come to with respect to selection of these reference-stars, in order that all the principal meridian observatories in the world may take part in observing them.

I venture to suggest that a Congress of astronomers should assemble in 1908 to consider what steps should be taken with reference to the important opposition of Eros in 1931.

The Stellar Universe.

And now to pass from consideration of the dimensions of our

* 'Monthly Notices R.A.S.,' Hinks, vol. lxiv. p. 725; Christie, vol. lxvii. p. 382.

solar system to the study of the stars, or other Suns, that surround us.

To the lay mind it is difficult to convey a due appreciation of the value and importance of star catalogues of precision. As a rule such catalogues have nothing whatever to do with discovery in the ordinary sense of the word, for the existence of the stars which they contain is generally well-known beforehand; and yet such catalogues are, in reality, by far the most valuable assets of astronomical research.

If it be desired to demarcate a boundary on the Earth's surface by astronomical methods, or to fix the position of any object in the heavens, it is to the accurate star-catalogue that we must refer for the necessary data. In that case the stars may be said to resemble the trigonometrical points of a survey, and we are only concerned to know from accurate catalogues their positions in the heavens at the epoch of observation. But in another and grander sense the stars are not mere landmarks, for each has its own apparent motion in the heavens which may be due in part to the motion of the solar system by which our point of view of surrounding stars is changed.

If we desire to determine these motions and to ascertain something of the general conditions which produce them, if we would learn something of the dynamical conditions of the universe and something of the velocity and direction of our own solar system through space, it is to the accurate star-catalogues of widely separated epochs that we must turn for a chief part of the requisite data.

The value of a star-catalogue of precision for present purposes of cosmic research varies as the square of its age and the square of its accuracy. We cannot alter the epoch of our observations, but we can increase their value fourfold by doubling their accuracy. Hence it is that many of our greater astronomers have devoted their lives chiefly to the accumulation of meridian observations of high precision, holding the view that to advance such precision is the most valuable service to science they could undertake, and comforted in their unselfish and laborious work only by the consciousness that they are preparing a solid foundation on which future astronomers may safely raise the superstructure of sound knowledge.

The Constitution of the Universe.

It was not until 1718, when Edmund Halley, afterwards Astronomer Royal of England, read a paper before the Royal

Society,* entitled "Considerations on the Change of the Latitudes of Some of the Principal Fixt Stars," that any definite facts were known about the constitution of the universe. In that paper Halley, who had been investigating the precession of the equinoxes, says: "But while I was upon this enquiry I was surprized to find the Latitudes of three of the principal Stars in heaven directly to contradict the supposed greater obliquity of the Ecliptick, which seems confirmed by the Latitudes of most of the rest."

This is the first mention in history of an observed change in the relative position of the so-called fixed stars—the first recognition of what we now call "proper motion."

Tobias Mayer, in 1760, seems to have been the first to recognize that if our Sun, like other stars, has motion in space, that motion must produce apparent motion amongst the surrounding stars; for in a paper to the Göttingen Academy of Sciences he writes:—"If the Sun, and with it the planets and the Earth which we inhabit, tended to move directly towards some point in the heavens, all the stars scattered in that region would seem to gradually move apart from each other, whilst those in the opposite quarter would mutually approach each other. In the same manner one who walks in the forest sees the trees which are before him separate, and those that he leaves behind approach each other." No statement of the matter could be more clear; but Mayer, with the meagre data at his disposal, came to the conclusion that "the motions of the stars are not governed by the above or any other common law, but belong to the stars themselves."

Sir William Herschel, in 1783, made the first attempt to apply, with any measure of success, Mayer's principle to a determination of the direction and amount of the solar motion in space.† He derived as well as he could from existing data, the proper motions of fourteen stars, and arrived by estimation at the conclusion that the Sun's motion in space is nearly in the direction of the star λ Herculis, and that 80 per cent of apparent motions of the fourteen stars in question could be assigned to this common origin.

This conclusion rests in reality upon a very slight basis, but the researches of subsequent astronomers show that it was an amazing accidental approach to truth—indeed, a closer approx-

* Phil Trans. 1718, p. 738.

† *Ibid.* 1783, p. 247.

imation than Herschel's subsequent determinations of 1805 and 1806, which rested on wider and better data.*

Consider for a moment the conditions of the problem. If all the stars except our Sun were at rest in space, then in accordance with Mayer's statement, just quoted, all the stars would have apparent motions on great circles of the sphere away from the apex and towards the antapex of the solar motion. That is to say, if the position of each star of which the apparent motion is known was plotted on the surface of a sphere and a line with an arrow-head drawn through each star showing the direction of its motion on the sphere, then it should be possible to find a point on the sphere such that a great circle drawn from this point through any star would coincide with the line of direction of that star's proper motion. The arrow-heads would all point to that intersection of the great circles which is the antapex of the solar motion, and the other point of intersection of the great circles would be the apex, that is to say, the direction of the Sun's motion in space.

But as the apparent stellar motions are small and only determinable with a considerable percentage of error, it would be impossible to find any point on the sphere such that every great circle passing through it and any particular star would in every case be coincident with the observed direction of motion of that star.

Such discordances would, on our original assumption, be due to errors of observation, but in reality much larger discordances will occur, which are due to the fact that the other stars (or suns) have independent motions of their own in space. This at once creates a new difficulty, viz., that of defining an absolute locus in space. The human mind may exhaust itself in the effort, but it can never solve the problem. We can imagine, for example the position of the Sun at any moment to be defined with reference to any number of surrounding stars, but by no effort of imagination can we devise means of defining the *absolute* position of a body in space without reference to surrounding material objects. If, therefore, the referring objects have unknown motions of their own, the rigor of the definition is lost.

What we call the observed proper motion of a star has three possible sources of origin:—

1. The *parallactic motion*, or the effect of our Sun's motion through space, whereby our point of view of surrounding celestial objects is changed.

* Phil. Trans. 1805, p. 233; 1806, p. 205.

2. The *peculiar* or particular motion of the star *i. e.*, its own *absolute* motion in space.

3. That part of the observed or tabular motion which is due to inevitable error of observation.

Secular Parallactic Motion of Stars.

Why should not the apparent parallactic motions of the stars, as produced by the Sun's motion in space, be utilized as a means of determining stellar parallax?

The strength of such determinations, unlike those made by the method of annual parallax, would grow with time. It is true that the process cannot be applied to the determination of the parallax of individual stars, because the peculiar motion of a particular star cannot be separated from that part of its apparent motion which is due to parallactic displacement. But what we specially want is not to ascertain the parallax of the individual star, but the mean parallax of a particular group or class of stars, and for this research the method is specially applicable, provided we may assume that the peculiar motions are distributed at random, so that they have no systematic tendency in any direction; in other words, that the center of gravity of any extensive group of stars will remain fixed in space.

This assumption is of course, but a working hypothesis, and one which, from the paper on star-streaming communicated by Professor Kapteyn of Groningen to the Johannesburg meeting of the Association two years ago, we already know to be inexact.* Kapteyn's results were quite recently confirmed in a remarkable way by Eddington,† using independent material discussed by a new and elegant method. Both results showed that, at least for extensive parts of space, there are a nearly equal number of stars moving in exactly opposite directions. The assumption then that the mean of the peculiar motions in zero may, at least for these parts of space, be still regarded as a good working hypothesis.

Adopting an approximate position of the apex of the solar motion, Kapteyn resolved the observed proper motions of the Bradley stars into two components, viz., one in the plane of the great circle passing through the star and the apex, the other at right angles to that plane.‡ The former component obviously includes the whole of the parallactic motion; the latter is inde-

* Rep. Brit. Assoc. 1905, p. 257.

† Monthly Notices R. A. S. vol. lxvii. p. 34.

‡ Publications Astron. Laboratory Groningen, Nos. 7 and 9.

pendent of it and is due entirely to the real motions of the stars themselves. From the former the mean parallactic motion of the group is derived, and from the combination of the two components the relation of velocity of the Sun's motion to that of the mean velocity of the stars of the group.

As the distance of any group of stars found by the parallactic motion is expressed as a unit in terms of the Sun's yearly motion through space, the velocity of this motion is one of the fundamental quantities to be determined. If the mean parallax of any sufficiently extensive group or class of stars was known, we should have at once means for a direct determination of the velocity of the Sun's motion in space; or if, on the other hand, we can by independent methods determine the Sun's velocity, then the mean parallax of any group of stars can be determined.

The Velocity of the Sun's Motion in Space.

If by this method the velocities in the line of sight of a sufficient number of stars situated near the apex and antapex of the solar motion could be determined, so that in the mean it could be assumed that their peculiar motions would disappear, we have at once a direct determination of the required velocity of the Sun's motion.

The material for this determination is gradually accumulating, and indeed much of it, already accumulated, is not yet published. But even with the comparatively scant material available, it now seems almost certain that the true value of the Sun's velocity lies between 18 and 20 kilometers per second*; or, if we adopt the mean value, 19 kilometers per second, this would correspond almost exactly with a yearly motion of the Sun through space equal to four times the distance of the Sun from the Earth.

Thus the Sun's yearly motion being four times the Sun's distance, the parallactic motion of stars in which this motion is unforeshortened must be four times their parallax. How this number varies with the amount of foreshortening is of course readily calculated. The point is that from the mean parallactic motion of a group of stars we are now enabled to derive at once its mean parallax.

This research has been carried out by Kapteyn for stars of different magnitudes. It leads to the result that the parallax of stars differing *five* magnitudes does *not* differ in the proportion

* Kapteyn, *Ast. Nach.* No. 3487, p. 108. and Campbell *Astrophys. Journ.* xiii. p. 80.

of one to ten, as would follow from the supposition of equal luminosity of stars throughout the universe, but only in the proportion of about one to five.*

The same method cannot be applied to groups of stars of different proper motions, and it is only by a somewhat indirect proof, and by calling in the aid of such reliable results of direct parallax determination as we possess, that the variation of parallax with proper motion could be satisfactorily dealt with.

As a final result Kapteyn derived an empirical formula giving the average parallax for stars of different spectral types and of any given magnitude and proper motion. This formula was published at Groningen in 1901†. Within the past few months the results of researches on stellar parallax, made under the direction of Dr. Elkin, at the Astronomical Observatory of Yale University, during the past thirteen years‡, have been published, and they afford a most crucial and entirely independent check on the soundness of Kapteyn's conclusions.

In considering the comparison between the more or less theoretical results of Kapteyn and the practical determinations of Yale, we have to remember that Kapteyn's tables refer only to the means of groups of a large number of stars having on the average a specified magnitude and proper motion, whilst the latter are direct determinations affected by the accidental errors of the separate determinations and by such uncertainty as attaches to the unknown parallaxes of the comparison stars—parallaxes which we have supplied from Kapteyn's general tables.

The Yale results consist of the determination of the parallax of 173 stars, of which only ten had been previously known to Kapteyn, and had been utilized by him. Dividing these results into groups, we get the following comparison:—

Comparison Groups arranged in order of Proper Motion.

No. of Stars	Proper Motion.	Magnitude.	Parallax		Yale—Kapteyn.
			Yale.	Kapteyn.	
	″		″	″	″
21	0.14	3.8	0.028	0.026	+0.002
39	0.49	6.3	.032	.055	— .013
45	0.59	6.7	.068	.060	+ .008
46	0.77	6.5	.047	.074	— .027
22	1.50	6.2	.118	.124	— .006

* *Ast. Nach.* No. 3487, Table III.; and *Ast. Journ.* p. 566.

† Publications Astron. Laboratory Groningen, No. 8, p. 24.

‡ Trans. Astron. Observatory of Yale Univ. vol. ii. part I.

Groups arranged in order of Magnitude.

10	0.61	0.8	0.103	0.110	—0.007
29	.53	3.8	.076	.075	+ .001
33	.63	5.6	.064	.070	— .006
34	.73	5.7	.055	.070	— .017
31	.68	7.6	.025	.061	— .036
36	.80	8.3	.056	.062	— .006

These results agree in a surprisingly satisfactory way, having regard to the comparatively small number of stars in each group and the great range of parallax which we know to exist amongst individual stars having the same magnitude and proper motion. In the mean perhaps the tabular parallaxes are in a minute degree too large, but we have unquestionable proof from this comparison that our knowledge of stellar distances now rests on a solid foundation.

THE OBSERVATORY, August, 1907.

TWO METHODS OF REDUCING POLARIS VERTICAL CIRCLE OBSERVATIONS FOR TIME WITH THE ENGINEER'S TRANSIT.

G. O. JAMES.

FOR POPULAR ASTRONOMY.

In a paper by Professor Seares* the necessary formulæ for reducing *Polaris Vertical Circle Observations with the Engineer's Transit* are deduced, and the object of this article is to transform these equations into those using the table of differences between the altitude of the Pole Star and the latitude, published each year in the *American Ephemeris and Nautical Almanac*, thereby avoiding the computation of special tables for the place of observation, and to give a rapid method of computing the rough chronometer correction necessary in the reduction. The method is by far the most accurate and easily applied of all those adapted to the ordinary engineer's transit, and is especially valuable for rough and approximate determinations in preliminary fieldwork. Because of the simplicity of the observation and the ease of reduction it yields good results even in the hands of an inexperienced observer, and with some practice and care will furnish a time determination with a probable error not exceeding 0.25 seconds of time, while a single set of two stars should determine the time to within a half second. This is sufficiently accurate for secondary azimuth work, and the method is therefore of great practical value in furnishing a subsidiary time determination in connection with secondary triangulation, a direction or repeating theodolite being well adapted to the observation.

* *Laws Observatory Bulletin* No. 5., Part II.

It would seem therefore that the method should have a prominent place in courses in field astronomy designed for surveyors, while as a matter of fact its use is almost unknown. It is true that for accurate determinations the labor of reduction is much greater than for observations nearly in the meridian, and hence it has found little use in this country, being mostly confined to Canada. On the other hand, for approximate work the reverse is true, and a study of the examples below will show this to be the case.

The equations developed in Professor Seares' paper are

$$G \equiv \frac{1}{1 - \tan p_0 \tan \phi \cos \tau_0},$$

$$\tau = -p_0 G \sec \phi \sin(\phi - \delta) \sec \delta \sin \tau_0,$$

$$\theta = \tau + \alpha,$$

$$\Delta\theta = \theta - \theta_c,$$

where:

$\phi \equiv$ observer's latitude,

$p \equiv$ star's north polar distance,

$\alpha \equiv$ star's right ascension,

$\delta \equiv$ star's declination,

$\tau \equiv$ star's hour angle,

$\theta \equiv$ local sidereal time,

$\theta_c \equiv$ chronometer sidereal time, and subscript $(_0)$ refers to Polaris.

G being a function of the polar distance and hour angle of Polaris and of the observer's latitude can be tabulated for a given latitude with the hour angle and year as arguments. The precessional change in p_0 being small will affect G only after a considerable time, and a given value of G may be used for a period of five years on each side of the tabulated year. For a place, therefore G need be tabulated at ten year intervals only. In the following table the intervals in the hour angle are one hour and the logarithms are given to four places.

$\phi = 38^\circ\ 57'$
1910 0

τ_0	log G	log G sec ϕ	τ_0
0^h	0.0072	0.1164	24
1	0.0070	0.1162	23
2	0.0063	0.1155	22
3	0.0051	0.1143	21
4	0.0036	0.1128	20
5	0.0019	0.1110	19
6	0.0000	0.1092	18
7	9.9981	0.1073	17
8	9.9964	0.1056	16
9	9.9949	0.1041	15
10	9.9938	0.1030	14
11	9.9931	0.1023	13
12	9.9929	0.1020	12

Five place tables are much more convenient for the reduction as will appear later, and tables giving log $G \sec \phi$ should be computed to five places and with correspondingly smaller intervals in the hour angle. Special tables for computing G are published in various places,† and the one referred to in the footnote gives log G with log $\tan p_0 \tan \phi \cos \tau_0$ as argument. Rough determinations can be made with the four place table above very rapidly as follows.

From the two equations

$$\tau_0 = \theta_0 - \alpha_0,$$

$$\tau = \theta - \alpha,$$

is obtained the rough value of the hour angle of Polaris,

$$\tau_0' = (\alpha - \alpha_0) - (\theta_c - \theta_{0c}).$$

A rough value of the hour angle of the Southern star is then,

$$\tau_0' = -p_0 G \sec \phi \sin(\phi - \delta) \sec \delta \sin \tau_0'.$$

From this $\Delta'\theta$ is obtained by means of

$$\theta' = \tau' + \alpha,$$

$$\Delta'\theta = \theta' - \theta_c.$$

Collecting the formulæ:

$$\tau_0' = (\alpha - \alpha_0) - (\theta_c - \theta_{0c}),$$
$$\tau' = -p_0 G \sec \phi \sin(\phi - \delta) \sec \delta \sin \tau_0',$$
$$\theta' = \tau' + \alpha,$$
$$\Delta'\theta = \theta' - \theta_c.$$

All logarithms are four place and the angles are taken to the nearest ten minutes of arc to avoid interpolation.

With an extended table for $G \sec \phi$, using the year and latitude as arguments, this rough reduction could be used at any station, but the necessity for such a table will be avoided by the transformation mentioned above.

Having obtained $\Delta'\theta$ the approximate reduction is carried on as follows, the value of log $G \sec \phi$ being taken from the table below, computed to five places.

† U.S. Coast and Geodetic Survey Report, 1897-98 Appendix No. 7, page 399.

log G sec ϕ.

1910.0

τ_o	0m	10m	20m	30m	40m	50m	60m	
0^h	0.11643	0.11643	0.11641	0.11636	0.11631	0.11626	0.11618	23^h
1	0.11618	0.11610	0.11599	0.11588	0.11574	0.11610	0.11547	22
2	0.11547	0.11529	0.11511	0.11493	0.11472	0.11452	0.11430	21
3	0.11430	0.11407	0.11383	0.11358	0.11333	0.11306	0.11279	20
4	0.11279	0.11252	0.11223	0.11194	0.11165	0.11135	0.11104	19
5	0.11104	0.11074	0.11043	0.11012	0.10981	0.10949	0.10918	18
6	0.10918	0.10886	0.10855	0.10824	0.10793	0.10763	0.10732	17
7	0.10732	0.10702	0.10673	0.10644	0.10615	0.10587	0.10560	16
8	0.10560	0.10534	0.10507	0.10482	0.10458	0.10434	0.10412	15
9	0.10412	0.10391	0.10371	0.10350	0.10333	0.10316	0.10299	14
10	0.10299	0.10285	0.10272	0.10258	0.10248	0.10237	0.10229	13
11	0.10229	0.10221	0.10216	0.10211	0.10206	0.10205	0.10205	12
12	0.10205	0.10205	0.10206	0.10211	0.10216	0.10221	0.10229	11
	60m	50m	40m	30m	20m	10m	0m	τ_o

Observation

Laws Observatory. Nov. 8, 1904.

Star	θ_{oc}			θ_c		
θ Piscium E	23^h	12^m	9^s	23^h	16^m	12.6
ι Piscium W		23	14		28	0.8
ι Aquarii W		29	46		33	4.2
δ Sculptoris E		35	43		38	3.7

Here the level error is made as small as possible by keeping the instrument level, touching up the screws when necessary, and the collimation error is eliminated by choosing pairs of stars of nearly equal declination, one being observed with the vertical circle east and the other west, the collimation corrections cancelling for the mean of each pair. Differences of from 5° to 10° in the declinations of a pair do not affect the result unless the collimation constant is large.

Computation of $\Delta'\theta$.

November 8, 1904.

Star	θ Piscium		
α	23^h	23^m	9^s
α_o	1	25	57
$\alpha - \alpha_o$	21	57	12
$\theta_c - \theta_{oc}$		4	3
τ_o'	21	53	9
p_o			288°
ϕ	38°	57′	
δ	5	51	
$\phi - \delta$	33	6	
$-p_o$	2.4594 n		
$G \sec \phi$	.1155		
$\sin(\phi - \delta)$	9.7380		
$\sec \delta$	.0023		
$\sin \tau_o''$	9.7212 n		
τ'	2.0364		
	0^h	1^m	49^s
θ'	23	25	58
θ_c	23	16	13
$\Delta'\theta$		8^m	45^s

Computation of $\Delta\theta$.
November 8, 1904.

Star	θ Piscium E			ι Piscium W			ι Aquarii W			δ Sculptoris E		
θ_{oc}	23^h	12^m	9^s	23^h	23^m	14^s	23^h	29^m	46^s	23^h	35^m	43^s
$\Delta'\theta$		8	45		8	45		8	45		8	45
θ_o	23	20	54	23	31	59	23	38	31	23	44	27
α_o	2	25	57	1	25	57	1	25	57	1	25	57
τ_o	21	54	57	22	6	2	22	12	34	12	18	31
p_o			$287^s.9$									
ϕ	38°	57′		38°	57′		38°	57′		38°	57′	
δ	5	51		5	7		−18	48		−28	40	
$\phi-\delta$	33	6		33	50		57	45		67	37	
$-p_o$	2.45924^n			2.45924^n			2.45924^n			2.45924^n		
$G\sec\phi$	.11529			.11561			.11561			.11574		
$\sin(\phi-\delta)$	9.73727			0.74568			9.92723			9.96598		
$\sec\delta$	.00227			.00173			.02381			.05679		
$\sin\tau_o$	9.71519^n			9.67866^n			9.65506^n			9.63200^n		
τ	2.02926			2.00092			2.18095			2.22975		
	0^h	1^m	$47^s.0$	0^h	1^m	$40^s.2$	0^h	2^m	$31^s.7$	0^h	2^m	$49^s.7$
α	23	23	8 .9	23	35	3 .8	23	39	16 .4	23	43	58 .4
θ	23	24	55 .9	23	36	44 .0	23	41	47 .0	23	46	48 .1
θ_c	23	16	12 .6	23	28	0 .8	23	33	4 .2	23	38	3 .7
$\Delta\theta$		8	43 .3		8	43 .2		8	43 .8		8	44 .4
Mean$\Delta\theta$		8^m	$43^s.7$	$\pm 0^s.3$								

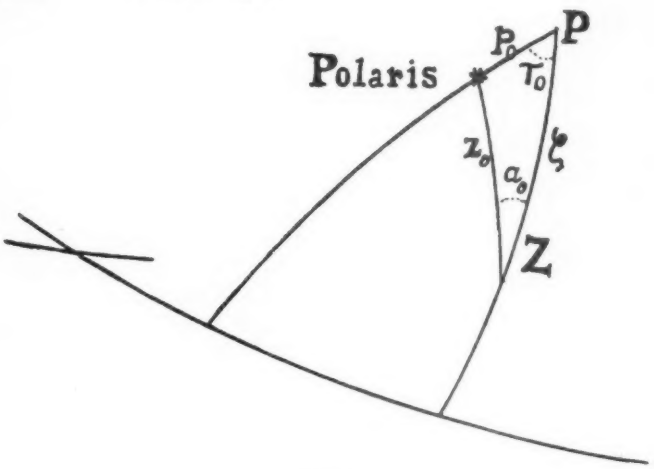


Figure 1

In the figure let

$P \equiv$ pole,
$Z \equiv$ zenith,
$\zeta \equiv$ colatitude,
$z_o \equiv$ zenith distance of Polaris,
$\alpha_o \equiv$ azimuth of Polaris,
$\tau_o \equiv$ hour angle of Polaris.

Then:

$$\sin a_o = \frac{\sin p_o \sin \tau_o}{\sin z_o} = \sin p_o \sec h_o \sin \tau_o.$$

Comparing this with the equation

$$\tan a_o = \tan p_o G \sec \phi \sin \tau_o,$$

it is seen that since both a_o and p_o are small angles, we may put

$$G \sec \phi = \sec h_o.$$

In the back of the *American Ephemeris and Nautical Almanac* is published each year a table giving the difference between the altitude of Polaris and the latitude, with the hour angle of Polaris as argument. This table is computed with a mean value of the declination of Polaris for the year and a latitude 45°, but is sufficiently accurate for any day in the year and any latitude up to 60°.

Calling this difference ϵ, in the sense

$$\phi = h_o + \epsilon,$$

we have

$$G \sec \phi = \sec(\phi - \epsilon),$$

and making this substitution the equation for the hour angle of the Southern star becomes

$$\tau = -p_o \sec(\phi - \epsilon) \sin(\phi - \delta) \sec \delta \sin \tau_o.$$

The use of a special table for $G \sec \phi$ is thus avoided, and the reduction is made to depend on a table already published each year. For fieldwork, where the stations are frequently changed, this is an advantage, as new tables would otherwise have to be computed for each station.

The reduction of the four stars given above by this method is then as follows.

The rough chronometer connection, $\Delta'\theta$, is given by the computation below, and the reduction for $\Delta\theta$ makes use of this preliminary chronometer correction.

Computation for $\Delta'\theta$.

November 8, 1904.

Star	θ Piscium		
α	23^h	23^m	9^s
α_o	1	25	57
$\alpha - \alpha_o$	21	57	12
$\theta_c - \theta_{oc}$		4	3
τ_o'	21	53	9
p_o			288^s

Star	θ Piscium
ϕ	38° 57′
ϵ'	−1 1
δ	5 51
$\phi-\epsilon'$	39 58
$\phi-\delta$	33 6
$-p_0$	2.4594^n
$\sec(\phi-\epsilon')$	.1157
$\sin(\phi-\delta)$	9.7380
$\sec\delta$	.0023
$\sin\tau_0'$	9.7212^n
τ'	2.0366
	0^h 1^m 49^s
θ'	23 25 58
θ_C	23 16 13
$\Delta'\theta$	8^m 45^s

Computation for $\Delta\theta$.

November 8, 1904.

Star	θ Piscium E	ι Piscium W	ι Aquarii W	δ Sculptoris E
θ_{0C}	23^h 12^m 9^s	23^h 23^m 14^s	23^h 29^m 46^s	23^h 35^m 43^s
$\Delta'\theta$	8 45	8 45	8 45	8 45
θ_0	23 20 54	23 31 59	23 37 31	23 44 27
α_0	1 25 57	1 25 57	1 25 57	1 25 57
τ_0	21 54 57	22 6 2	22 12 34	22 18 31
p_0	$287^s.9$			
ϕ	38° 57′	38° 57′	38° 57′	38° 57′
ϵ	−1 2	−1 3	− 1 4	− 1 5
δ	5 51	5 7	−18 48	−28 40
$\phi-\epsilon$	39 59	40 0	40 1	40 2
$\phi-\delta$	33 6	33 50	57 45	67 37
$-p_0$	2.45924^n	2.45924^n	2.45924^n	2.45925^n
$\sec(\phi-\epsilon)$	.11564	.11675	.11585	.11596
$\sin(\phi-\delta)$	9.73727	9.74568	9.92723	0.96598
$\sec\delta$	.00227	.00173	.02381	.05679
$\sin\tau_0$	9.71519^n	9.67866^n	9.65506^n	9.63200^n
τ	2.02961	2.00106	2.18119	2.22997
	0^h 1^m $47^s.1$	0^h 1^m $40^s.2$	0^h 2^m $31^s.8$	0^h 2^m $49^s.8$
α	23 23 8 .9	23 35 3 .8	23 39 16 .3	23 43 58 .4
θ	23 24 56 .0	23 36 44 .0	23 41 48 .1	23 46 48 .2
θ_C	23 16 12 .6	23 28 0 .8	23 33 4 .2	23 38 3 .7
$\Delta\theta$	8 43 .4	8 43 .2	8 43 .9	8 44 .5
Mean $\Delta\theta$	8^m $43^s.8$			

If a chronometer regulated to sidereal time is not available, a mean time chronometer may be used, and the mean times converted into the corresponding sidereal times by means of the working formulæ

$$\theta = T + \Delta''' T + ☉ + \Delta''' \lambda,$$
$$T = (\theta - ☉) - \Delta''(\theta - ☉) - \Delta''\lambda,$$

where:

$T \equiv$ local mean time,
$\theta \equiv$ local sidereal time,
$☉ \equiv$ right ascension of mean Sun at preceding Greenwich mean noon.

The corrections Δ'' and Δ'' for reducing a sidereal interval to the corresponding mean interval and conversely are tabulated in tables II and III at the end of the *Ephemeris*.

For rough reduction the observed mean interval need not be reduced to sidereal interval to obtain the rough hour angle of Polaris since $T_c - T_{oc}$ is very nearly equal to $\theta_o' - \theta_{oc}$, and we may write

$$\tau_o' = (\alpha - \alpha_o) - (T_c - T_{oc}).$$

The longitude need be known only roughly for the conversion, since it enters only through $\Delta''\lambda$ and $\Delta'''\lambda$, corrective terms of small magnitude; an error of 37 seconds of time in λ producing an error of $0^s.1$ in the final result. For the rough determination λ may be assumed or taken from a map while for the approximate determination it is supposedly known roughly from previous work.

The following pair of stars were observed with a mean time chronometer of unknown correction on local time, and reduced as follows.

Observation.

W.U. May 7, 1905.

Star	T_{oc}	T_c
α Virginis E	$10^h\ 15^m\ 17^s$	$10^h\ 20^m\ 3^h{}^s$
π Hydræ W	10 53 45	11 2 11

Computation for $\Delta' T$.

May 7, 1005.

Star	α Virginis		
α	13^h	20^m	13^s
α_o	1	24	17
$\alpha - \alpha_o$	11	55	56
$\tau_c - \tau_{oc}$		5	16
τ_o'	11	50	40
p_o			289^s
ϕ	38°	$39'$	
ϵ'	1	12	
δ	-10	40	
$\phi - \epsilon'$	37	27	
$\phi - \delta$	49	19	
$-p_o$	2.4609^n		
$\sec(\phi - \epsilon')$	.1002		
$\sin(\phi - \delta)$	9.8778		
$\sec \delta$	.0076		
$\sin \tau_o'$	8.6097		
τ'	1.0582^n		
			-11^s
α	13	20	13
θ'	13	20	2
ⓜ	3	58	38
$\theta - $ ⓜ	10	21	24
Δ''		2	41
τ'	10	18	43
τ_c	10	20	24
$\Delta'\tau$		-1^m	51^s

The correction on standard time, obtained the following day, was

$$\Delta T_{90} = -36^s,$$

and this gave for a rough value of the longitude

$$\Delta\lambda_{90} = \Delta T_{90} - \Delta' T = 1^m\ 15^s.$$

In the rough reduction a longitude of 6 hours was used as Washington University is a little west of the 90th meridian.

Computation for ΔT.

May 7, 1905.

Star	α Virginis E			π Hydræ W		
T_c	10^h	115^m	17^s	10^h	53^m	45^s
$\tau_\odot$	10	13	26	10	51	54
⑨	2	58	38	2	58	38
Δ'''		2	41		2	46
θ_c	13	14	45	13	53	18
α_c	1	24	17	1	24	17
$\tau_\odot$	11	50	28	12	29	1
$p_\odot$		288".5				
ϕ	38°	39′		38°	39′	
ϵ	1	12		1	12	
δ	−10	40		−26	14	
$\phi - \epsilon$	37	27		37	27	
$\phi - \delta$	49	19		64	55	
$-p_\odot$	2.46015"			2.46015"		
$\sec(\phi-\epsilon)$	.10024			.10024		
$\sec(\phi-\delta)$	9.87985			9.95698		
$\sec\delta$	.00757			.04721		
$\sin\tau_\odot$	8.61894			9.10131"		
τ	1.06675"			1.66589		
			−11".7			46".3
α	13^h	20^m	13.1	14^h	0^m	59.8
θ	13	20	1.4	14	1	46.1
⑨	2	58	38.0	2	58	38.0
$\theta - ⑨$	10	21	23.4	11	3	8.1
Δ''		2	40.9		2	47.8
T	10	18	42.5	11	0	20.3
T_c	10	20	33.0	11	2	11.0
ΔT		− 1	50.5		−1	50.7
Mean ΔT		− 1^m	50".6			

The most convenient five place tables for the computations of this paper are those in which the trigonometric functions are given with both arc and time as arguments on the same page, and the *Fünfstellige Mathematische u. Astronomische Tafeln* of *Bidschof-Vital* are especially well arranged for this work. The *Geographic Tables and Formulas*, published by the U. S. Geological Survey, Washington 1904, can also be used, although not quite as conveniently, as they do not give the secants and cosecants.

Washington University,
St. Louis, Missouri.
August, 1904.

ON A METHOD OF COMPUTING ϕ—ϕ' AND ρ.

FRANCIS RUST, C.E.

FOR POPULAR ASTRONOMY.

The method of computing approximately the value of analytical expressions, by expanding them into series, is too well-known and its value too generally acknowledged, to require any explanation. But however useful this method is in cases where only an approximate value is obtainable, its application in other cases may complicate the calculations and even lead to erroneous theories. To direct the reader's attention to one very interesting sample of such a complication, and to submit a suggestion for redressing it, is the object of the following.

In determining the corrections for parallax in astronomical observations are required:* the difference between the geographic latitude (ϕ) and the geocentric latitude (ϕ') and also the ratio $\frac{\rho}{a}$ of the local radius of our Earth to the radius of the Earth's equator. Both magnitudes are given in all books on Astronomy by series, not at all for simplification.

The meridian section of Earth is an ellipse, the geographic latitude ϕ of any point M on its surface is the angle intercepted by this point's Normal and its projection upon the plane of the equator, and the geocentric latitude is the angle intercepted by the radius OM of said point and its projection upon the plane of the equator.

Referring the ellipse to its axes OX and OY we have:

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} - 1 = 0 \qquad (1)$$

from which we derive by differentiation:

$$\frac{dy}{dx} = -\frac{x}{y} \cdot \frac{b^2}{a^2} \qquad (2)$$

* The reader will remember the formulæ for parallax in Azimuth and Zenith distance:

$$(A - A')'' = p_0'' \cdot \sin(\phi - \phi') \frac{\sin A}{\sin z}$$

$$(z - z')'' = p_0'' \sin [z - (\phi - \phi') \cos A]$$

A and z are values observed for Azimuth and Zenith distance; A' and z' are their corrected values and p_0 is the local horizontal parallax of the body observed. If π designates its horizontal equatorial parallax

$$p_0 = \frac{\rho}{a} \cdot \pi .$$

From our diagram we see:

$$\frac{y}{x} = \tan\phi'$$

and

$$\frac{dy}{dx} = \tan\psi = -\cot\phi$$

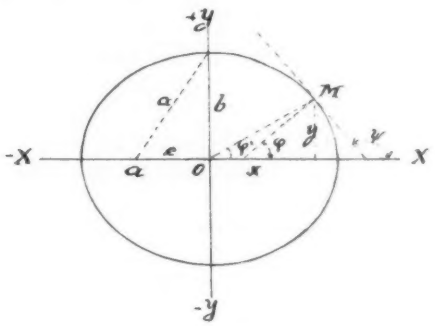
consequently results:

$$\tan\phi' = \frac{b^2}{a^2} \cdot \tan\phi \qquad (3)$$

For any ellipse there is:

$$\sqrt{a^2 - b^2} = e$$

the distance of its foci from the center and $\epsilon = \frac{e}{a}$ is considered the numerical expression of its eccentricity.



Considering ϵ as the sine of a certain angle, the angle of eccentricity makes

$$\epsilon = \sin\kappa = \frac{e}{a} = \sqrt{1 - \frac{b^2}{a^2}},$$

consequently

$$\cos\kappa = \frac{b}{a} \qquad (4)$$

and therewith we may put down equation (3)

$$\tan\phi' = \cos^2\kappa \cdot \tan\phi \qquad (5)^*$$

*The angle κ for the meridian section of Earth is given differently by different authorities. American astronomers apply:

$$\log\sin\kappa = 8.9152515 \text{ or } \kappa = 4^\circ\ 43'\ 9''$$

(Washington Nautical Almanac.)

Equation (5) surely affords a simpler way to determine the difference $(\phi - \phi')$, than does the series:

$$(\phi - \phi') = 11' 40''.44 \sin 2\phi - 1''.19 \sin 4\phi + \quad *$$

and moreover the series above is leading to a mistake.

Evidently for $\phi = 0$ and for $\phi = 90°$, $\phi' = \phi$ and their difference vanishes, consequently it must have a maximum value and the above series makes it appear as if that maximum value would occur for $\phi = 45°$ and would be $\phi - \phi' = 11' 40''.44$ *which is not the case.*

From equation (3) we derive:

$$\tan(\phi - \phi') = \frac{\tan\phi - \tan\phi'}{1 + \tan\phi \tan\phi'}$$

$$= \frac{a^2 - b^2}{a^2 \cot\phi + b^2 \tan\phi}$$

and differentiating for ϕ

$$(\phi - \phi') = \text{arc tan} \frac{a^2 - b^2}{a^2 \cot\phi + b^2 \tan\phi}$$

results in:

$$\frac{d(\phi - \phi')}{d\phi} = \frac{(a^2 - b^2)\left[\frac{a^2}{\sin^2\phi} - \frac{b^2}{\cos^2\phi}\right]}{(a^2 \cot\phi + b^2 \tan\phi)^2 + (a^2 - b^2)^2}.$$

This expression becomes zero for

$$\frac{a}{\sin\phi} = \frac{b}{\cos\phi} \quad \text{or} \quad \tan\phi = \frac{a}{b}$$

or, by equation (3) for

$$\tan\phi' = \frac{b}{a}$$

which means that the difference $(\phi - \phi')$ is at its maximum when ϕ and ϕ' are complimentary angles and this takes place for

$$\tan\phi' = \cot\phi = \frac{b}{a} = \cos\kappa.$$

For the values of κ used by the astronomers in charge of the Washington Nautical Almanac, this maximum is located under latitude 45° 5′ 50″.21: and its amount

$$\phi - \phi' = 11' 40''.42$$

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* Also Washington Nautical Almanac.

For the ratio $\frac{\rho}{a}$ there is given also a series, determining the logarithm of that magnitude:

$$\log\frac{\rho}{a} = 9.9992645 + 0.0007374 \cos 2\phi \\ - 0.0000019 \cos 4\phi \\ + \ldots\ldots$$

Easier than by this series, we obtain the required ratio by making in equation (1)

$$x = \rho \cos\theta \quad \text{and} \quad y = \rho \sin\theta.$$

This results in the equation of the ellipse, expressed in polar coördinates with the center as pole and the major axis as polar axis.

$$\rho = \frac{ab}{\sqrt{a^2 \sin^2\theta + b^2 \cos^2\theta}} \qquad (6)$$

the polar angle θ being identical with the geocentric latitude ϕ'.

Dividing in (6) both sides by a and the right hand side of it in numerator and denominator by b results in

$$\frac{\rho}{a} = \frac{1}{\cos\theta\sqrt{1 + \frac{a^2}{b^2}\tan^2\theta}}$$

and if we now introduce ϕ' for θ and tan ϕ for $\frac{a^2}{b^2}$ tan ϕ' makes

$$\frac{\rho}{a} = \frac{1}{\cos\phi'\sqrt{1+\tan\phi\tan\phi'}}$$

$$= \sqrt{\frac{\cos\phi}{\cos\phi'\cos(\phi-\phi')}}. \qquad (7)$$

The influence of cos $(\phi-\phi')$ becomes noticeable only when logarithms of more than five decimals are applied. For the accuracy afforded by five decimal logarithms it is sufficient to use:

$$\frac{\rho}{a} = \sqrt{\frac{\cos\phi}{\cos\phi'}}. \qquad (8)$$

Formulas (7) and (8) become indefinite for low latitudes and for the poles. If we return to equation (6), replace under the sign of radication b by $a \cos\kappa$ and divide in numerator and denominator by a, we get:

$$\rho = \frac{b}{\sqrt{\sin^2\theta + \cos^2\kappa \cos^2\theta}}$$

and by introducing

$$\cos^2 \kappa \cos^2 \theta = (1-\sin^2 \kappa)\ (1 - \sin^2 \theta)$$
$$= 1 - \sin^2 \kappa - \sin^2 \theta + \sin^2 \kappa \sin^2 \theta,$$

the last equation transforms into

$$\rho = \frac{b}{\sqrt{\cos^2 \kappa + \sin^2 \kappa \sin^2 \theta}}$$

or dividing numerator and denominator by $\cos \kappa$

$$\frac{\rho}{a} = \frac{1}{\sqrt{1 + \tan^2 \kappa \sin^2 \theta}}.$$

The polar angle is identical with the geocentric latitude ϕ', consequently if we exchange and introduce an auxiliary angle μ:

$$\tan \mu = \tan \kappa \sin \phi'$$

we obtain from our last equations:

$$\frac{\rho}{a} = \cos \mu \qquad (9)$$

Equation (9) applies of course generally, but for mean latitudes equation (7) or (8) may be deemed more convenient.

Equations (6) (7) (8) and (9) undoubtedly serve to solve the problems for ϕ' and ρ with better facility and greater accuracy than the series now in general use; the deducement of those series consequently appears to be a waste of mental labor.

Allegheny, Pa.

THE TRANSIT OF MERCURY, NOVEMBER 14, 1907, AS VISIBLE IN THE UNITED STATES.

Wm. F. RIGGE, S. J.

For Popular Astronomy

The United States will be very unfavorably situated for viewing the coming transit of Mercury on November 14, 1907. About one-third of the states will not see the planet at all upon the Sun's face, and the others will only get a glimpse of its egress and that at a low altitude above the horizon. On Figure 1 the line marked 0 is the limiting line of visibility, all places to the west of it not seeing the transit at all. This 0 line, as well as those marked 10 and 20, show the degrees of the Sun's altitude at the moment of egress. The broken lines 6, 7, 8, 9, indicate the places at which sunrise will occur at 6, 7, 8, 9, o'clock central time.

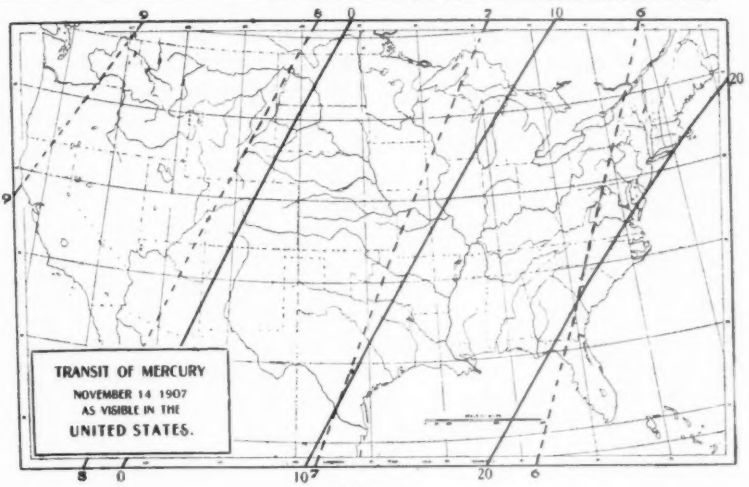


Figure 1.

Figure 2 represents the disk of the Sun with its cardinal points N S E W, its vertex at the time of the planet's egress being with-

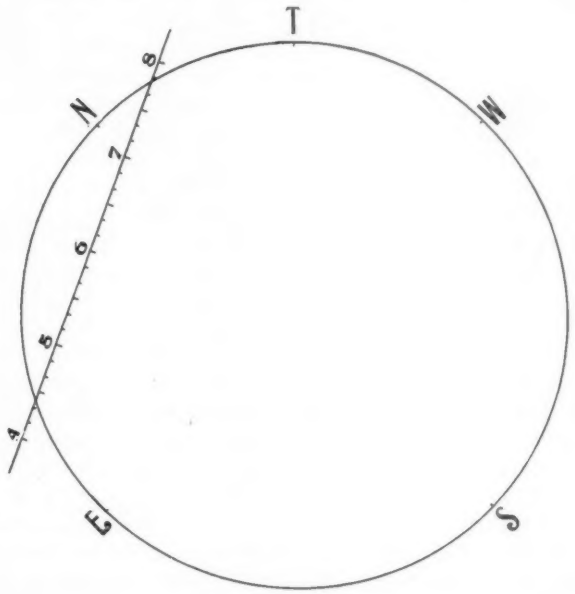


Figure 2.

in 15° of the point T for every place within the United States. The position of the planet is marked for every full hour and every ten minutes of central time. The egress will occur at about 7:49 A. M., central time, the computed times of the third and fourth contacts for Omaha being $7^h\ 48^m\ 16^s.6$ and $7^h\ 50^m\ 55^s.6$, the Sun rising at 7:11. As Mercury's diameter is only $\frac{1}{194}$ that of the Sun, a telescope will be necessary to see it.

The next transit, November 7, 1914, will be very much like the present one, the egress only being visible in the United States. On May 7, 1924 and November 11, 1940 the ingress only will be visible to us. The transit of November 9, 1927, will be entirely invisible, and the first transit completely visible in the United States will not occur until November 14, 1953.

Creighton University, Observatory,
Omaha, Nebraska.

THE RILLS ON THE MOON.

[Extract from Chapter V, THE MOON, by Ph. Fauth.]

We now consider a last category of lunar features that are often found on the map, and still more frequently on the Moon itself, and that will give us a new light on the solidity of the material of our satellite. These are the breaches, clefts, or 'rills.' They have nothing in common with river-courses or anything of that description. They are quickly recognized by the practiced eye on account of their reversed relief. Whilst the heights are bright on the side that lies nearest the Sun, and dark on the opposite side, it is, of course, just the reverse with depressions. The rills may, it is true, run in such an unfavorable direction as regards the Sun's rays that they show hardly any trace of light and shade; in that case one needs prolonged research before forming an opinion as to their real nature. They have been compared to terrestrial gorges, to the valley of the Rhine between Bingen and Coblenz, to ravines like the Via mala, or to cañons of Colorado. But, on the strength of an acquaintance with several hundreds of well-placed rills, we hold that these comparisons are quite unjustified especially when they are based closely on the *apparent* features, which are so deceptive on the Moon. If we take the Rhine-valley *below* Coblenz and the whole plain of the upper Rhine as extremes, taking account of both depressions and flatness, no doubt the lunar rills will come somewhere between the two. Whether the finest of the rills in the

MAP OF THE RING-MOUNTAIN GASSENDI,
BY PH. FAUTH
(1 mm. = 940 m.)

Moon's shell are still steeper and deeper we cannot say; we are fortunate to perceive them at all.

There are, however, two quite distinct types, the flat and broad rills, and the narrow ones that we can hardly tell the depth of. The 'great valley' near Herodotus and the 'valley of the Alps' are the largest and earliest known of these objects. There are also the 200-mile long rill of Ariadæus, the Hyginus-rill, the wide canal at the foot of Plinius, the three chief rills near Hippalus, the 170-mile long cleft between Hesiodus and Capuanus, the great valley inside Petavius, etc. The narrow ones are the most numerous, they are sometimes very long, sometimes short, like fine cracks. The system of rills about Triesnecker, the clefts in Posidonius, Gassendi, and Ramsden, are so many examples. What makes the rills so interesting from the selenological point of view is that they so often make their appearance round areas of subsidence or inside them (Gassendi?). It is evident that this phenomenon has occurred round the borders of the Mare humorum and the Mare serenitatis. Where they seem to be lacking, we find a cognate structure, the long and flat mountain-veins, which are clear signs of earlier cleavage-lines in the Maria serenitatis, humorum, and nectaris, they run more or less parallel to the shores. Further, the ranges of hills that run in bold, S-shaped, flat curves from the ring mountain Lambert towards the southwest, north, and northeast, are nothing more than earlier ruptures, filled up to overflow with a fluid that issued from below and solidified. In this case we willingly endorse the Meydenbauer-Thiersch theory of meteoric impact, which may have been the cause of the bursting of the Moon's shell. Since Professor Prinz proved* by many experiments and illustrations the reality of the apparent features, and showed that brittle masses split generally in three different directions at the place of impact or of least resistance, the frequent occurrence of three rays on the mountain-veins and the frequent triangular and hexagonal form of the ring-structures (Godin, Ptolemæus, and many others) are no longer very puzzling. Rills must generally be regarded as secondary and subsidiary formations, and they help us to appreciate the brittleness of the solid matter of the Moon.

In this connection it would not be out of place to recall the abrupt gradation of the plains, as we find in Thebit, where it is known as 'the long wall' (78 miles) or (in England) 'the rail-

* *Esquisses sélénologiques.* See also his *L'échelle réduite des expériences géologiques.*

way'. The steep fall lies toward the east, so that it only casts shadows in the first quarter of the Moon. The author has on careful examination, recognized at the foot of the wall the line of rupture and some remarkable details; Gaudibert also detected the rupture. There is a similar case on the western edge of the chief rill near Cauchy, and something like it, though without a rill, is seen to the west of Cassini. In order to appreciate these details we must carefully bear in mind what we saw above as to the possible origin of these terraced falls.

We have already observed that the broader valleys were the first to be discovered. Schroeter found 11 rills, and with the improvement of the achromatic telescope and of our knowledge of the rills the number increased. Mädler has indicated 77 of them; Lohrmann, with rather better instruments, 99; Schmidt gives on his map no less than 348 of these very elusive objects. Schmidt did not think the number was exhaustive, and conjectured that they would prove to be about 500. His successors have added a few, though there was little choice in reproducing them. Gaudibert gives 324 (partly new ones) on his map of 1885, and Neison gave 366 in 1881. But we shall only get reliable and very desirable information about the number of the rills in particular, and the centers of rupture in general, from some such study of the Moon's topography as L. Brenner is making, in small tracts, at Lussinpiccolo, where some 360 new rills have been discovered, or as the author is making on a larger scale with the object of producing a map 11 feet in diameter. The author has discovered a further 1,258 rills in a small portion of the Moon's surface, and these make up 1,600 with Schmidt's indications.

MATHEMATICS NEEDED FOR PROFESSIONAL ASTRONOMY.

W. W. PAYNE.

For Popular Astronomy.

The field of astronomy has become so large that no one person can expect to be very skilful in all branches of it. This is not only true now, but it is constantly becoming more and more so as time goes on.

On this account it is a very important question for the student of astronomy to ask himself early in his study, what is the preparation I most need to pursue the study of astronomy most

successfully. The answer to this query will depend, in a measure, on the purpose the student has in mind when he plans to undertake it. If he only cares for a mere outline of the subject, that may be gained by easy popular reading, almost any amount of scholarly preparation which he may happen to have will probably answer his purpose; for he does not expect to put time and energy enough into his work in the study to advance very far in it, if he should comprehend something of the extent of the theme in its breadth and its depth.

We are not now to consider the wants of the student who is thinking about the subject in this way, but rather our purpose is to offer some suggestions to any who may want to do something in astronomy that shall be more nearly systematic and finished work in the study, no matter to what extent he may be able to pursue it. After many years of study and teaching of the college mathematics and the college astronomy, so-called, we have come to the conclusion, that the most important thing that should be in the mind of a young person who enters upon these studies is that what he does should be done in a complete, orderly and finished manner. The essential elements to such a course of preparation must be for the average mind willing to work hard and long, the mastery of the best books in these sciences, the instruction of competent teachers, the advice of experienced and skilful scholars and the advantages of a reference library. At the present time all of these important things are within the reach of any young person who has the best in mind and the determination to succeed at any reasonable cost or outlay of mental energy. Whatever course one is to pursue in science, pure mathematics or astronomy, a thorough knowledge of Algebra is the first great essential in preparation. All mathematics beyond Algebra in the ordinary college courses so largely depend on this branch, that no student can expect to succeed in the pursuit of studies following it, unless he has mastered thoroughly and well all the Algebra that is offered in the best colleges of the present time.

It is a lamentable fact that our high schools are doing so little in Algebra that their graduates generally are woefully deficient in preparation for the college work in this branch which they ought to have done when they come to it. The result of this poor preparation puts the student at a great disadvantage in all his science work and especially so in the pursuit of the various branches of the higher mathematics which one must know if he is to follow almost any one of the many callings now open to young

men and young women who are seeking something more remunerative than mere manual labor or routine work.

What the student most needs in Algebra is a thorough knowledge of variation, proportion, elimination including the methods of determinants, a complete and a ready knowledge of quadratics extending into the theory of equations, and a full and quite exhaustive mastery of series including the application of the theory of limits. The method of the infinitesimal analysis properly belongs to Algebra. It is surprising to the writer that some experienced teachers and authors of text-books on Algebra claim that infinitesimal analysis does not belong to Algebra, but to the Calculus. As well might it be said that the method of limits should find place only in the Calculus, for the necessary final step to reach the result of a limit proof involves the concept of the infinitesimal and there is no escape from it.

This preparation in Algebra is very much strengthened, if the student will apply these principles to many exercises, and amply test his knowledge of them in a large number of problems involving the uses of them. In exercises which should come first, the idea of method in simple application is the leading one; but in the study of problems the student comes to a wider use of principle and application; for he must then invent, and synthetically construct equations dependent on the explicit or implicit conditions of the problems in hand. Too much emphasis probably can not be laid on this part of the preparation of the student in Algebra who wishes either to instruct in the higher mathematics, or, later in life, to pursue some professional course in modern science. The writer believes the best way to get this needed preparation in Algebra, after a person has done the ordinary text-book work in high school or college is to secure the best general text-book on modern Algebra within reach, and then to make a masterful study of it, after council with some practical mathematician who knows better than any student can know what he should aim at, and how he may best accomplish what he is planning to do. This point is strongly advised, because no general outline like the one we are now giving can be sufficiently particular to reach individual cases. In preparing it we are fully aware that it will raise more questions in individual cases than we answer in this general way; but the object of it all is gained because the student is directed in his general planning which is vastly more important to him in the entrance upon a life-work than a fuller knowledge of the details of its plan which will unfold later as the work is prosecuted in the years that follow.

It would be easy to name good books in Algebra that fulfill these conditions as they are understood by the writer; but that suggestion could be made in a better way to the individual when it is known what his preparation in Algebra has been, and what he aims to do in the future. If his purpose be a complete preparation in this branch for professional work in practical astronomy there is, at present, no work on Algebra that contains all of these points, probably in the best way, but there are some late books in this branch that come sufficiently near to the standard to be called almost ideal. Boyd's College Algebra gives an illustration of what we mean as a fairly good text and reference book, for an advance student to have at hand. If the second course in Algebra by Albert Harry Wheeler is as good as the First Course bound in one volume of 650 pages and published during the present year, the two volumes will make a desirable set for the same purpose. There are, of course, other late authors that might well be referred to as possessing merit in this larger way and for these larger uses, but these we have noticed are particularly adapted for the work here outlined.

The subject of Geometry should next claim the attention of the student preparing himself for advanced work in mathematics and astronomy. In the elementary courses in the secondary schools the main purpose is to drill the student in the essentials of correct deductive reasoning. Models of method and easy, appropriate original exercises from the body of the work are to be done by the student as he passes through this stage. In this part of his study, he is forming a habit of a kind of thinking that is new and quite different from that which has occupied the mind in the study of Algebra, even in its more advanced parts. In the Algebra the unit of value is in the sense of number, and the properties of number open a wide field for operations of arithmetical kind. The study in this direction is now advancing in new and surprising ways and mathematicians are looking for discoveries that may be of great service to general Arithmetic and Algebra.

But the fundamental thing in advanced studies in Geometry is not only method in reasoning in the ordinary logical way; but it is also a critical study of definitions, axioms, premises and conclusions. As grave errors in final conclusions may be made in any one of these particular lines of thinking as it is possible to make in faulty reasoning on accepted axioms, definitions and premises. The deductive logic of Geometry is potent when every step of its exact processes is well taken. This broad field of

logic in mathematics is a most fertile one if the advanced student will only cultivate it for himself very thoroughly. It is scarcely necessary to say to the student who is in touch with the recent progress of work done in what is called the non-Euclidean Geometry, that much is coming to light to explain the difficult and the unsatisfactory points in the older methods of the science especially in regard to framing definitions and in knowing something of the limitations of axioms that the science of Geometry may be made as broad as possible, and still throughout its whole range rigorously exact.

Such advanced studies in Geometry will not fail to show the student the difference between deductive and inductive proofs. This is important because any true conclusion must depend on the nature of the proofs, in regard to relevancy and completeness. If proofs are purely and wholly deductive, all other conditions being certain and true, the conclusion reached by such proofs must be rigorously true, and therefore entirely satisfactory. This is not the case in the use of inductive proofs. At best a probability of the truth of the conclusion reached by inductive proofs can only be affirmed. In such a case the degree of probability which the proofs will reach must also depend on relevancy and completeness and the necessity of shutting out every other conclusion which is, in any sense, contrary to the one sought to be established. Such proofs can never reach the quality of absolute certainty, for if that were possible the extent of the proofs would have passed the limits of induction, and their nature would be certainly deductive. For such a theoretically wide induction could be surely replaced by a simple chain of deductive proofs that would very agreeably change the method of reaching the conclusion.

Such studies as these in Geometry will help the student in another serious and life-long task, viz:—that of weighing proofs. What the logic of Geometry may do for a student who will systematically make much of it, in thinking, in writing and in speaking is beyond any estimate of value that can be stated in words. Something of its value has been realized by great men in all modern times. Pythagoras knew it well and often spoke of it in his lectures. It was the source of the marvelous insight of Sir Isaac Newton, and the instrument by which the brilliant discoveries of the Principia were published to the world. It was the genius of a Plato, the mental grasp of LaPlace, the polished clearness of LaGrange, the bold rigor of Gauss as he applied its simple principles to hard problems in new fields of analytical study.

It has been a powerful and sometimes a merciless weapon in the political arena. As an example of this one has only to remember how Daniel Webster trained himself almost daily in the demonstrations of Geometry until he could wield its two-edged sword without an equal in stern and relentless logic in the halls of the American Congress.

It is to be regretted that the writer can not point to any one book that would serve as a guide to a student who desires a general and somewhat complete view of the whole field of ancient and modern Geometry for the purposes of study as herein outlined. So far as he knows such a work has not yet been written. But it is true that there are many excellent books that are devoted to the different branches of Geometry that are within the reach of most students that will serve the purpose fairly well, under the guidance of a scholarly mathematician for an ample preparation in the pure logic of Geometry. In the earlier study if we consult Archimedes, Descartes, Pascal and Desaurges that noble field is well opened. In the nineteenth century Geometry the progress has been astonishing great. For an outline view of what has been accomplished Dr. Morgan's Study of Mathematics,[1] Smith's Teaching of Elementary Mathematics[2], Casey's Sequel to Euclid[3], Ball's History of Mathematics,[4] Fink's Brief History of Mathematics,[5] Hilbert's Foundations of Geometry,[6] translated by Townsend, Higher Mathematics by Merriman and Woodward[7]. This list could be extended almost indefinitely; but enough has been said to give an outline idea of this splendid field open to modern scholarship in the mathematics.

To be Continued.

[1] The Study of Mathematics, De Morgan, The Open Court Publishing Co., Chicago, 1902.

[2] The Teaching of Elementary Mathematics. The Macmillan Co., New York, 1901.

[3] Casey's Sequel to Euclid. The Hodges Co., Dublin, Ireland.

[4] Macmillan Co., N. Y., 1893.

[5] Open Court Publishing Co., Chicago, 1903.

[6] Open Court Publishing Co., Chicago, 1902.

[7] Wiley & Sons, New York, 1896.

PERTH OBSERVATORY MERIDIAN WORK.

W. ERNEST COOKE.*

FOR POPULAR ASTRONOMY.

Perth Observatory has just issued a catalogue of 420 standard stars. As this is the first astronomical volume issued from the Perth Observatory a few words as to our present and proposed future work will not be out of place.

We have undertaken the zone 32° - 40° south declination for the International Photo Durchmusterung. Nearly all the necessary photographs (for the catalogue portion) have been taken, but the measurement is only now being commenced. In all probability we shall not be able to take the long exposure photographs for mechanical reproduction.

In order to obtain the plate constants three stars have been selected, where practicable, in every square degree, and these are being observed with the transit circle. This work was commenced on 1901 October 6. Each observation consists of transit over seven vertical wires and readings of four microscopes. The instrument is a modern one by Messrs. Troughton & Simms, having a clear aperture of 6 inches. The "seeing" is usually good and the definition excellent.

The old method, which was first adopted, of determining clock error from equatorial stars of the Nautical Almanac, and the nadir point from reflections over the mercury trough, was not considered satisfactory and was definitely abandoned on 1905 July 28, after we had completed zones 32°, 33°, 39°, and 40°, and part of 33° - 34°. It was then determined to obtain both clock error and equator point from standard stars situated within, or close to the zone of observation. Auwer's "Fundamental Catalog für Zonenbeobachtungen am Südhimmel" was accepted as the basis of the system, but since at least three reference stars per hour are required for each zone of 2° it was necessary to choose a number of stars to act as secondary standards, and to observe these a considerable number of times. This has been done and the present catalogue is the result. It will be adopted as fundamental in the zone reductions until the whole zone of 31° - 41° is completed; and the results previously obtained between 1901 October 6, and 1905 July 28 will be reduced as well as possible to the present system.

In a few years a satisfactory determination (three complete observations) of the positions of some eight to ten thousand stars

* Government Astronomer for Western Australia.

fairly well distributed over the region 31° to 41° will be obtained, and these will be used for the determination of the plate constants in the astrographic catalogue.

Now a few words as to the future of transit work. I have adopted a plan which I hope to see copied by a number of other observatories. I propose that the Perth Observatory shall confine its transit observations to this particular region and prepare a catalogue of exactly the *same stars* every 10 or 12 years, or as frequently as possible, including each time a redetermination of the 420 secondary standards. Thus in the course of time the worker in this part of the sky will turn to the Perth catalogues with the certainty of finding a number of stars in any ordinary sized field all of whose positions have been regularly determined from time to time and can therefore be brought reliably up to date.

Notwithstanding the millions of observations which have been taken and the hundreds of existing catalogues there are very few parts of the sky in which the above condition exists. It is earnestly hoped that this attempt to place meridian work upon a more satisfactory basis may be followed by others, so that the output of energy may be concentrated upon some systematic measuring of the sky instead of being squandered as it has been to some extent in the past. In particular I hope that when their present program is finished the four Australian Observatories will coöperate in order to maintain a systematic survey of the region 20° to 60° south declination.

Perth, Australia,
Observatory, June 26, 1907.

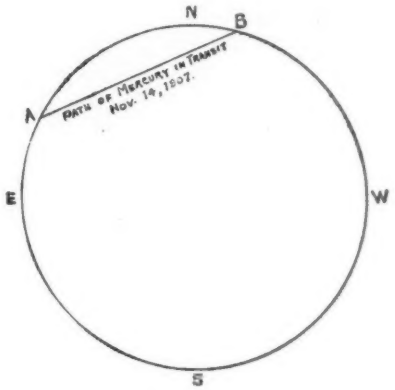
"The spectrum of the corona appears to possess a triple origin: a continuous spectrum, both original and reflected, and a gaseous of bright line emissions; these vary at times, the discontinuous being feeble, especially near the sunspot minimum epoch. About a dozen coronal lines have been observed with the spectroscope. The fundamental green ray designated as the 'Coronium line' was traced to a distance of 325,000 miles in the corona during the eclipse of 1889 by Keeler, but it is still of an unknown substance. The original continuous spectrum appears to emanate from incandescent solid or liquid particles from the interior corona, and seem to be of a phosphorescent nature with little or no thermal radiations. The reflected continuous spectrum is slight, but clearly present at times, and mainly in the remoter portions of the corona, Perrine having found thirty-five Fraunhofer lines in his study of the photographic results of the eclipse of 1901. This reflected light is probably due to dust or fog according to Young, or some matter which reflects sunlight: polariscopic observations also confirm the presence of reflected light."

[From David E. Hadden's Address before the Sioux City Academy of Science and Letters, entitled "Progress and Problems of Solar Physics during the Last Fifty Years."]

PLANET NOTES FOR NOVEMBER 1907.

H. C. WILSON.

Mercury will be stationary in right ascension, at the east end of the Z-shaped loop in Libra, on November 3, and will move westward until November 22, passing between the Earth and Sun on the morning of November 13. At this time a transit of Mercury across the disk of the Sun will be visible in Europe. In the United States the Sun will rise with Mercury upon its disk. The ingress of the planet upon the Sun's disk will be visible generally in Europe, Africa,



western and central Asia, western Australia and South America; the egress in Europe except the northeast portion, Africa, western Asia, South America and North America except the northwest portion. The following data taken from the *American Ephemeris* for 1907, will enable the reader to calculate the times of the different phases of the transit for his own locality (See also the article by William F. Rigge on page 448 in this number of POPULAR ASTRONOMY).

Times of the Geocentric Phases.

	Greenwich Mean Time				Central Standard Time.			
	d	h	m	s	d	h	m	s
Ingress, exterior contact	Nov. 13	22	23	39.9	Nov. 13	16	23	39.9
Ingress, interior contact	13	22	26	19.3	13	16	26	19.3
Least distance of centers 12′ 38″.3	14	0	06	47.7	13	18	06	47.7
Egress, interior contact	14	1	47	18.3	13	19	47	18.3
Egress, exterior contact	14	1	49	57.8	13	19	49	57.8

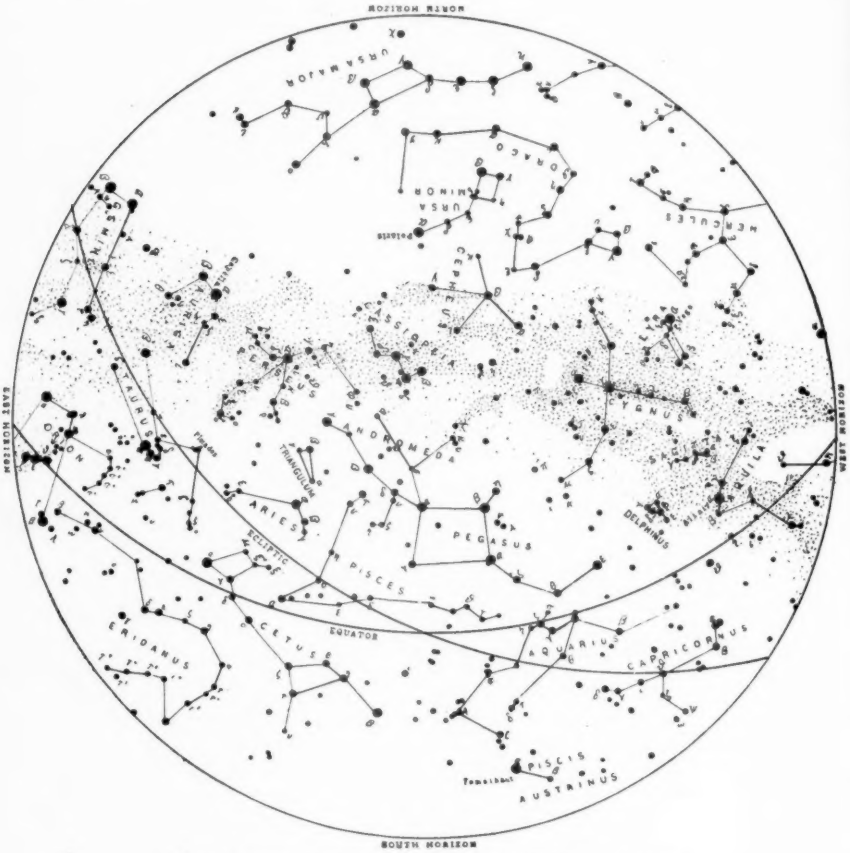
Angles of Position from the North point of the Sun's Disk.

Ingress, exterior contact	62°	30′	East
Ingress, interior contact	61	46	East
Egress, interior contact	14	39	West
Egress, exterior contact	15	23	West.

The Greenwich mean times of the four contacts for any point on the surface of the Earth may be computed from the four following formulæ, respectively, in which ρ denotes the radius of the Earth at that point, ϕ' the geocentric north latitude, and λ the latitude *west* from Greenwich. The numbers in brackets are the logarithms of the respective coefficients.

	h	m	s		°	′	″
Ing. ext. =	22	23	39.9	− [1.4665] $\rho \sin \phi'$ − [1.7723] $\rho \cos \phi' \cos$ (258	02	7	− λ)
Ing. int. =	22	26	19.3	− [1.4837] $\rho \sin \phi'$ − [1.7767] $\rho \cos \phi' \cos$ (258	59	7	− λ)
Eg. int. =	1	47	18.3	+ [1.7922] $\rho \sin \phi'$ + [1.4077] $\rho \cos \phi' \cos$ (	72	18.5	− λ)
Eg. ext. =	1	49	57.8	+ [1.7838] $\rho \sin \phi'$ + [1.4091] $\rho \cos \phi' \cos$ (	74	26.7	− λ]

At the end of the month Mercury will be at greatest elongation, west of the Sun 20° 20′, and so may be seen as morning star.



THE CONSTELLATIONS AT 9:00 P. M., NOVEMBER 1, 1907.

Venus will be visible in the evening, toward the southwest from a half to three-quarters of an hour after sunset. On November 6 Mercury will be about two degrees south of Venus.

Mars will be at quadrature, 90° east from the Sun, November 11. The planet may be seen toward the south and southwest in the evening in the constellation Capricorn. It has begun now to ascend the slope of the ecliptic and is coming

into slightly better position for observation, but at the same time, its distance from the Earth is rapidly increasing, so that its apparent disk is becoming smaller and the surface markings therefore less distinct.

Jupiter is a morning planet, on the meridian about 6^h a. m., in the constellation Cancer. He will be at quadrature, 90° west from the Sun, November 5 and will reach his position farthest east among the stars for the year on December 1.

Saturn is in good position for study, except for the fact that the rings are turned nearly edgewise to us. He is in Aquarius directly south of the Square of Pegasus, seen near the meridian at about nine o'clock in the evening. The planet's motion will be slow, westward until November 25, and after that eastward.

Uranus will be too low in the southwest for study at the close of the evening twilight. An occultation of Uranus by the Moon will take place November 9. (See Oc. Vis. at Washington).

Neptune may be found with the aid of a good telescope, among the faint stars between two and three degrees southwest of δ Geminorum, nearly midway between the stars δ and ζ. Its position for November 1 is

R. A. $7^h\ 4^m\ 1^s$, Dec. $+21°\ 47'$.

Occultations visible at Washington.

Date 1907	Star's Name	Magnitude.	IMMERSION. Washington M.T.	Angle f'm N.	EMERSION. Washington M.T.	Angle f'm N	Duration.
			h m	°	h m	°	h m
Nov. 9	URANUS	..	4 37	140	5 37	255	1 00
15	Lalande 2632	6.5	12 22	0	12 59	301	0 37
20	BD. $+19°$, 811	6.2	16 12	110	17 18	237	1 06
21	ζ Tauri	3.0	9 51	47	10 58	279	1 07
23	δ Geminorum	3.5	8 56	103	9 55	245	0 59
24	Piazzi viii, 42	6.0	14 08	104	15 41	272	1 33

Satellites of Saturn.

[The diagram of the orbits of the satellites cannot be shown since the Earth passes the planes of the orbits at different times during September and October.]
Central Standard Time reckoning from noon.

I Mimas. Period $0^d\ 22^h.6$.

		h			h			h
Nov.	1	8.5 W.	Nov. 9	8.7 E.	Nov. 17	9.0 W.	Nov. 26	7.8 E.
	2	7.1 W.	10	7.3 E.	18	7.6 W.	27	6.5 E.
	3	5.7 W.	11	5.9 E.	19	6.2 W.	28	5.1 E.
	6	12.8 E.	12	4.5 E.	20	4.9 W.		
	7	11.5 E.	15	11.8 W.	24	10.6 E.		
	8	10.1 E.	16	10.5 W.	25	9.2 E.		

II Enceladus. Period $1^d\ 8^h.9$.

Nov.	1	18.7 E.	Nov. 10	0.0 E.	Nov. 18	5.4 E.	Nov. 26	10.7 E.
	3	3.6 E.	11	8.9 E.	19	14.3 E.	27	19.6 E.
	4	12.5 E.	12	17.8 E.	20	23.1 E.	29	4.5 E.
	5	21.4 E.	14	2.7 E.	22	8.0 E.	30	13.4 E.
	7	6.3 E.	15	11.6 E.	23	16.9 E.		
	8	15.2 E.	16	19.5 E.	25	1.8 E.		

III Tethys. Period $1^d\ 21^h.3$.

Nov.	2	4.1 E.	Nov. 9	17.3 E.	Nov. 17	6.5 E.	Nov. 24	19.8 E.
	4	1.4 E.	10	14.6 E.	19	3.8 E.	26	17.1 E.
	5	22.7 E.	13	11.9 E.	21	1.1 E.	28	14.4 E.
	7	20.0 E.	15	9.2 E.	22	22.5 E.	30	11.7 E.

IV Dione. Period $2^d\ 17^h.7$.

		h			h			h			h
Nov.	1	18.7 E.	Nov.	9	23.7 E.	Nov.	18	4.7 E.	Nov.	26	9.8 E.
	4	12.3 E.		12	17.4 E.		20	22.4 E.		29	3.5 E.
	7	6.0 E.		15	11.1 E.		23	16.1 E.			

V Rhea. Period $4^d\ 12^h.4$.

Nov.	3	15.6 E.	Nov.	12	16.4 E.	Nov.	21	17.2 E.	Nov.	30	18.1 E.
	8	4.0 E.		17	4.8 E.		26	5.6 E.			

VI Titan. Period $15^d\ 22^h.7$.

Nov.	1	12.9 E.	Nov.	9	13.5 W.	Nov.	17	11.2 E.	Nov.	25	12.0 W.
	5	16.4 I.		13	9.1 S.		21	14.8 I.		29	7.8 S.

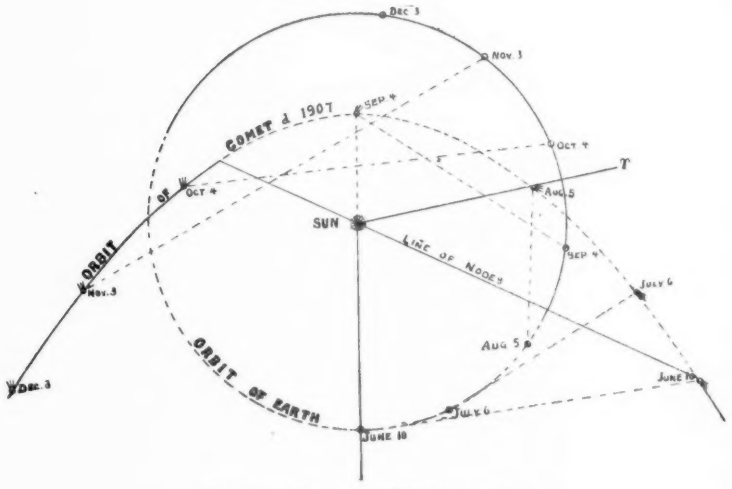
VII Hyperion. Period $21^d\ 06^h.6$.

Nov.		1.0 E.	Nov.		13.3 I	Nov.		22.3 S.	Nov.		28.3 E.
		7.5 E.			17.9 W.						

VIII Iapetus. Period $79^d\ 7^h.9$.

Oct.		29.3. E	Nov.		18.3 I.	Dec.		8.6 W.	Dec.		28.4 S.

COMET NOTES.



ORBIT OF COMET *d* 1907 (DANIEL).

Diagram of the Orbit of Comet *d* 1907 (Daniel). The accompanying diagram was prepared with the aid of the elements by Georg Dybeck given in our last number. As the comet's plane of motion is inclined only 9° to the plane of the Earth's orbit, the foreshortening of the one orbit by projecting it upon the plane of the other is insignificant. It will readily appear from an inspection of the diagram that the comet when discovered was farther from the Earth than the Earth from the Sun and that for a time the distance between the two rapidly diminished. The comet was nearest the Earth's orbit about July 26. Had it reached that point a month and a half later than it did, the comet might have been a much more magnificent object in the heavens than it has been. Its actual nearest approach to the Earth was about August 1,

when it was about 70,000,000 miles distant. Since that time it has been moving away from us rapidly and turning in nearer into line with the Sun. It will not however pass behind the Sun, because our motion around the latter will keep the comet in view and we may be able to follow it with the great telescopes until next summer.

Observations of Comet *d*. The atmosphere on August the 12th between 3 and 4 A.M. being clear and free from moonlight, the head of comet *d* was observed with a low power in a field of view one degree in diameter. The instrument used was a four-inch Brashear refractor. In aspect, the interesting visitor differed much from the cometary bodies that have visited northern skies for many years past. Its nucleus had a stellar luster with a planetary extent of surface. Jupiter is too white and large for comparison, Mars, too reddish, but in size, the golden nucleus resembled the Martian disk during a favorable opposition. The smoke colored coma extended sunward about eight minutes of an arc, and continuing to the same extent on each side, gave the outline a large headed appearance as there was little increase of width below the nucleus. The latter distinct in size and color seemed to have escaped the haziness of its flossy envelope and was in striking contrast to the somber tint around. Gray and gold were the

COMET *d* 1907, AUGUST 19, 3:15 A. M.

leading effects. The faint gray of the telescopic comet gradually condensing to the lighter gray of its nucleus bears no resemblance to this beautiful object in what seems to have been its largest phase. Its tail was disappointing however. Though visible to the naked eye for several degrees, its greatest width was near the head from which it tapered in dim scanty streaks. After an interval of cloudy mornings a second view was obtained on August the 19th. The ethereal coma was decreased in its sunward extension, and the nucleus seemed less brilliant and sharply defined. Being within a few minutes of an arc of the fourth magnitude star, Lambda Geminorum, the coma must have passed centrally over that star in the ensuing hours of daylight. The tail extended visibly to the naked eye within a few degrees of Gamma ten degrees westward.

To avoid the light of dawn on the 26th and 28th, the next clear mornings that occurred, it was necessary to view the comet when pretty close to the horizon. At the same time the gibbous Moon was in the western sky; and to these

causes a marked decline in the seeming size of the head and in the luster of the nucleus were, no doubt, partly due. Under favorable conditions it was much superior to the Rordame comet of July 1893.

ROSE O'HALLORAN.

San Francisco,
Sept. 3, 1907.

VARIABLE STARS.

Approximate Magnitudes of Variable Stars on Sept. 1, 1907.

[Communicated by the Director of Harvard College Observatory, Cambridge, Mass.]

Name.	R. A. 1900. h	m	Decl. 1900. °	′	Magn.	Name.	R. A 1900 h	m	Decl. 1900 °	′	Magn.
X Androm.	0	10.8	46	27	9.0 *i*	RS Librae	15	18.5	−22	33	11.1*d*
T Androm.		17.2	+26	26	11.7*d*	RU Librae		27.7	−14	59	8.8
T Cassiop.		17.8	+55	14	8.2 *i*	X Librae		30.4	−20	50	12.5
R Androm.		18.8	+38	1	9.3*d*	W Librae		32.2	−15	51	11.5
Y Cephei		31.3	+79	48	<12	S Urs. Min.		33.4	+78	58	7.5 *i*
U Cassiop.		40.8	+47	43	10.2 *i*	U Librae		36.2	−20	52	9.4 *i*
V Androm.		44.6	+35	6	9.7*d*	Z Librae		40.7	−20	49	13.2*d*
RR Androm.		45.9	+33	50	8.5	R Coronae		44.4	+28	28	6.0
W Cassiop.		49.0	+58	1	8.5	R Serpentis		46.1	+15	26	9.5*d*
U Androm.	1	9.8	+40	11	11.5*d*	V Coronæ		46.0	+39	52	11.2*d*
Y Androm.		33.7	+38	50	11.5 *i*	RR Librae		50.6	−18	1	13.5*d*
X Cassiop.		49.8	+58	46	11.7*d*	RZ Scorpii		58.6	−23	50	13.5
U Persei		53.0	+54	20	10.6*d*	R Herculis	16	1.7	+18	38	13.0*d*
R Arietis	2	10.4	+24	35	10.0*d*	Z Scorpii		0.1	−21	28	9.5
Z Cephei		12.8	+81	13	<12	RR Herculis		1.5	+50	46	9.6*d*
S Persei		15.7	+58	8	10.2*d*	U Serpentis		2.5	+10	12	8.0 *i*
R Trianguli		31 0	+33	50	9.0	X Scorpii		2.7	−21	16	<13.5
Y Persei	3	20.9	+43	50	8.5	W Scorpii		5.9	−19	53	13 *i*
R Persei		23 7	+35	20	11.5 *i*	RX Scorpii		5.9	−24	38	13.8*d*
T Camelop.	4	30.4	+65	57	12.5*d*	RU Herculis		6.0	+25	20	11.2*d*
R Aurigae	5	9.2	+53	28	11.8 *i*	R Scorpii		11.7	−22	42	<13.5
S Camelop.		30.2	+68	45	8.0 *i*	S Scorpii		11.7	−22	39	11.0*d*
U Aurigae		35.6	+31	59	8.0 *i*	W Coronae		11.8	+38	3	13.8*d*
S Lyncis	6	35.9	+58	0	10.0 *i*	W Ophiuchi		16.0	− 7	28	10.8 *i*
Y Draconis	9	31.1	+78	18	8.0 *i*	V Ophiuchi		21.2	−12	12	10.7*d*
R Urs. Maj.	10	37.6	+69	18	11.8 *i*	U Herculis		21.4	+19	7	9.3*d*
R Comae	11	59.1	+19	20	9.0*d*	Y Scorpii		23.8	−19	13	11.5*d*
T Can. Ven.	12	25.2	+32	3	9.0 *i*	SS Herculis		28.0	+ 7	3	8.7 *i*
T Urs. Maj.		31.8	+60	2	12.2*d*	T Ophiuchi		28.0	−15	55	13.0*d*
R Virginis		33.4	+ 7	32	9.0 *i*	S Ophiuchi		28.5	−16	57	13.6*d*
RS Urs. Maj.		34.4	+59	2	11.7*d*	W Herculis		31.7	+37	32	13.5
S Urs. Maj.		39.6	+61	38	10.7*d*	R Draconis		32.4	+66	58	9.0*d*
T Urs. Min.	13	32.6	+73	56	13.5	RR Ophiuchi		43.2	−19	17	8.0 *i*
R Can. Ven.		44.6	+40	2	11.5 *i*	S Herculis		47.4	+15	7	12.8*d*
Z Bootis	14	1.7	+13	59	8.7*d*	RV Herculis		56.8	+31	22	9.5 *i*
S Bootis		19.5	+54	16	8.8d	R Ophiuchi	17	2.0	−15	58	13.7*d*
RS Virginis		22.3	+ 5	8	9.0 *i*	RT Herculis		6.8	+27	11	13.0*d*
V Bootis		25.7	+39	18	11.3*d*	Z Ophiuchi		14.5	+ 1	37	8.4 *i*
R Camelop.		25.1	+84	17	10.0*d*	RS Herculis		17.5	+23	1	8.0
R Bootis		32.8	+27	10	12.5*d*	RS Ophiuchi		44.8	− 6	40	11.0
V Librae		34.8	−17	14	12.3*d*	RT Ophiuchi		51.8	+11	11	9.5 *i*
U Bootis		49.7	+18	6	12.5	T Draconis		54.8	+58	14	10 *i*
RT Librae	15	0.8	−18	21	9.2 *i*	RY Herculis		55.4	+19	29	11.2*d*
T Librae		5.0	−19	38	13 *d*	V Draconis		56.3	+54	53	13 *d*
Y Librae		6.4	− 5	38	13.3	T Herculis	18	5.3	+31	0	10.2*d*
S Librae		15.6	−20	2	9.5*d*	W Draconis		5.4	+65	56	9.7 *i*
S Serpentis		17.0	+14	40	8.0 *i*	X Draconis		6.8	+66	8	13.5
S Coronae		17.3	+31	44	11.5*d*	W Lyrae		11.5	+36	38	8.6*d*

Approximate Magnitudes of Variable Stars on Sept. 1, 1907—Con.

Name.	R. A. 1900. h	m	Decl. 1900. °	′	Magn.	Name.	R.A. 1900. h	m	Decl. 1900. °	′	Magn.
T Serpentis	18	23.9	+ 6	14	13.5	W Capric.	20	8.6	−22	17	<13.8
RZ Herculis		32.7	+25	58	10.0 *i*	Z Aquilae		9.8	− 6	27	12.5*d*
X Ophiuchi		33.6	+ 8	44	7.8*d*	RS Cygni		9.8	+38	28	9.3*d*
RY Lyrae		41.2	+34	34	<14	R Delphini		10.1	+ 8	47	8.5 *i*
RW Lyrae		42.1	+43	32	9.7 *i*	RT Capricorni		11.3	−21	38	7.5
RX Lyrae		50.4	+32	42	<14	SX Cygni		11.6	+30	46	11.0
ST Sagittarii		55.9	−12	54	<13.5	WX Cygni		14.8	+37	8	11.0
Z Lyrae		56.0	+34	49	<13.5	V Sagittae		15.8	+20	47	12.3
RT Lyrae		57.8	+37	22	<14	U Cygni		16.5	+47	35	10.0*d*
R Aquilae	19	1.6	+ 8	5	10.4 *i*	RW Cygni		25.2	+39	39	8.8*d*
V Lyrae		5.2	+29	30	<13.8	RU Capric.		26.7	−22	2	12.5*d*
RX Sagittarii		8.7	−18	59	12.5*d*	S Delphini		38.5	+16	44	11.0 *i*
RW Sagittarii		8.1	−19	2	9.5	V Cygni		38.1	+47	47	12.5 *i*
S Lyrae		9.1	+25	50	13.5	T Delphini		40.7	+16	2	12.5*d*
RS Lyrae		9.3	+33	15	<13.8	V Aquarii		41.8	+ 2	4	8.3*d*
RU Lyrae		9.1	+41	8	11.0 *i*	W Aquarii		41.2	− 4	27	8.5
U Draconis		9.9	+67	7	10.0*d*	U Capricorni		42.6	−15	9	11.0 *i*
W Aquilae		10.0	− 7	13	13.5*d*	V Delphini		43.2	+18	58	<13.7
T Sagittae		10.5	−17	9	8.7*d*	T Aquarii		44.7	− 5	31	10.8*d*
R Sagittae		10.8	−19	29	8.2 *i*	X Delphini		50.3	+17	16	13.0 *i*
RY Sagittae		10.0	−33	42	7.0	UX Cygni		50.9	+30	2	13.0
S Sagittae		13.6	−19	12	10.0	R Vulpeculae		59.9	+23	26	7.8 *i*
Z Sagittarii		13.8	−21	7	<1.38	V Capric.	21	1.8	−24	19	10.8
TZ Cygni		13.4	+50	0	11.5	TW Cygni		1.8	+29	0	<13.8
U Lyrae		16.6	+37	42	<13	X Cephei		3.6	+82	40	<13.8
T Sagittae		17.2	+17	28	9.5	T Cephei		8.2	+68	5	7.8*d*
TY Cygni		29.8	+28	6	9.0 *i*	S Cephei		36.5	+78	10	10.2*d*
RT Aquilae		33.3	+11	30	8.5	RR Pegasi		40.0	+24	33	10.5 *i*
R Cygni		34.1	+49	58	11.5*d*	RT Pegasi		59.8	+34	38	9.5 *i*
RV Aquilae		35.9	+ 9	42	12.5	Y Pegasi	22	6.8	+13	52	10.0 *i*
RT Cygni		40.8	+48	32	11.0*d*	RS Pegasi		7.4	+14	4	8.5 *i*
TU Cygni		43.3	+48	49	12.0*d*	S Lacertae		24.6	+39	48	10.4 *i*
X Aquilae		46.5	+ 4	13	<13	R Lacertae		38.8	+41	51	10.5*d*
X Cygni		46.7	+32	40	12.0*d*	S Aquarii		51.8	−20	53	8.0
RR Aquilae		52.4	− 2	11	12.0*d*	R Pegasi	23	1.6	+10	0	8.5 *i*
RS Aquilae		53.7	− 8	9	<13.5	V Cassiop.		7.4	+59	8	8.5 i
Z Cygni		58.6	+49	46	13.2*d*	W Pegasi		14.8	+25	44	12.5*d*
S Cygni	20	3.4	+57	42	<14	S Pegasi		15.5	+ 8	22	9.6*d*
R Capricorni		5.7	−14	34	13.8	R Aquarii		38.6	−15	50	8.5 *i*
S Aquilae		7.0	+15	19	10.0 *i*	R Cassiop.		53.3	+50	50	6.5
RU Aquilae		8.0	+12	42	11.2	Y Cassiop.		58.2	+55	7	13.5

The letter *i* denotes that the light is increasing, the letter *d* that the light is decreasing, the sign <, that the variable is fainter than the appended magnitude.

The magnitudes given above have been compiled by Mr. Leon Campbell of the Harvard College Observatory, from observations made at the Whiteside and Harvard Observatories.

Maxima of Variable Stars of Short Period not of the Algol Type.

Unless otherwise indicated the times of maxima only are given; and the times of minima may be found by subtracting the interval printed in parentheses under the names of the stars.

RW Cassiop.		RX Aurigæ		Y Aurigæ		Y Aurigæ		Y Aurigæ	
d	h	d	h	d	h	d	h	d	h
(−5	19)	(−4	0)	(−0	18)				
Nov. 11	7	Nov. 5	9	Nov. 2	16	Nov. 14	6	Nov. 29	17
26	2	17	0	6	13	18	3	T Monoc.	
		28	15	10	10	21	23	(−7	23)
						25	20	Nov. 19	9

Maxima of Variable Stars of Short Period not of the Algol Type.

Continued.

W Geminorum

d	h
(−2	22)
Nov. 1	9
9	7
17	5
25	3

ζ Geminorum

d	h
(−5	0)
Nov. 10	10
20	14
30	18

V Carinæ

d	h
(−2	4)
Nov. 5	14
12	7
18	23
25	16

T Velorum

d	h
(−1	10)
Nov. 5	4
9	19
14	11
19	2
23	17
28	9

W Carinæ

d	h
(−1	0)
Nov 4	14
8	23
13	8
17	17
22	1
26	10
30	19

S Muscæ

d	h
(−3	11)
Nov. 7	16
17	7
26	23

T Crucis

d	h
(−2	2)
Nov. 2	19
9	12
16	6
22	23
29	17

R Crucis

d	h
(−1	10)
Nov. 1	14
7	9
13	5
19	1
24	21
30	17

S Crucis

d	h
(−1	12)
Nov. 3	2
7	18
12	11
17	3
21	20
26	12

W Virginis

d	h
(−8	5)
Nov. 9	14
26	20

RV Ophiuchi
Minimum

Nov. 4	5
7	21
11	14
15	6
18	23
22	15
26	8
30	0

X Sagittarii

d	h
(−2	22)
Nov. 7	18
14	18
21	19
28	19

Y Ophiuchi

d	h
(−6	5)
Nov. 8	2
25	4

W Sagittarii

d	h
(−3	0)
Nov. 6	18
14	8
22	23
29	14

Y Sagittarii

d	h
(−2	2)
Nov. 3	12
9	6
15	1
20	19
26	14

U Sagittarii

d	h
(−2	23)
Nov. 2	14
9	8
16	2
22	20
29	14

β Lyrae

(−3	2)
(−3	7)
Nov. 6	17
13	9
19	15
26	7

κ Pavonis

d	h
(−4	7)
Nov. 4	5
13	7
22	9

U Aquilae

d	h
(−2	4)
Nov. 2	12
9	13
16	13
23	14
30	14

XZ Cygni

d	h
Period 11h.2	
(−0	4)
Nov. 1	0
1	22
2	21
3	19
4	18
5	16
6	14
7	13
8	11
9	10
10	8
11	6
12	5
13	3
14	2
15	0
15	22
16	21
17	19
18	18
19	16
20	14
21	13
22	11
23	10
24	8
25	6
26	5
27	3
28	2
29	0
29	22
30	21

U Vulpeculae

d	h
(−2	3)
Nov. 7	1
15	1
23	0

SU Cygni

d	h
(−1	7)
Nov. 3	2
6	23
10	19
14	15
18	11
22	8
26	4
30	0

η Aquilae

d	h
(−2	6)
Nov. 4	8
11	13
18	17
25	21

S Sagittae

d	h
(−3	10)
Nov. 6	9
14	18
23	4

V Vulpeculae

d	h
Minimum	
Nov. 5	5

X Cygni

d	h
(−6	19)
Nov. 12	2
28	11

T Vulpeculae

d	h
(−1	10)
Nov. 2	5
6	15
11	2
15	12
19	23
24	9
28	20

TX Cygni

d	h
Nov. 2	7
17	1

WZ Cygni
Minimum
Period 14h.0

Nov. 1	2
2	6
3	10
4	14
5	18
6	22
8	2
9	6
10	10
11	14
12	18
13	22
15	3
16	7
17	11
18	15
19	19
20	23
22	3
23	7
24	11
25	15
26	19
27	23
29	3
30	7

RV Capricorni
Period 10h.7

Nov. 1	19
2	16
3	14
4	11
5	9
6	6
7	5
8	1
8	23
9	20
10	18

RV Capricorni

d	h
Nov. 11	15
12	13
13	10
14	8
15	5
16	3
17	0
17	22
18	19
19	17
20	14
21	11
22	9
23	6
24	4
25	1
25	23
26	20
27	18
28	15
29	13
30	10

VY Cygni

d	h
(−2	2)
Nov. 7	7
15	3
23	0
30	20

VZ Cygni

d	h
(−2	12)
(−3	6)
Nov. 6	21
11	21
16	15
21	15
26	8
Dec. 1	8

δ Cephei

d	h
(−1	10)
Nov. 2	14
8	22
14	7
19	16
25	1
30	01

V Lacertæ

d	h
(−1	17)
Nov. 2	17
7	17
12	16
17	16
22	16
27	15

88.1906

Lacertæ

d	h
Nov. 6	2
11	12
16	23
22	10
27	20

Minima of Variable Stars of the Algol Type.

[Given to the nearest hour in Greenwich Mean Time beginning with noon. To reduce to Central Standard time subtract 6 hours, or for Eastern time subtract 5 hours.]

U Cephei

	d	h
Nov.	1	19
	4	6
	6	18
	9	6
	11	18
	14	6
	16	18
	19	5
	21	17
	24	5
	26	17
	29	4

Z Persei

Nov.	3	10
	6	11
	9	12
	12	14
	15	15
	18	16
	21	18
	24	19
	27	21

RX Cephei

Nov.	18	23

Algol

Nov.	1	5
	4	2
	6	23
	9	20
	12	16
	15	13
	18	10
	21	7
	24	4
	27	0
	29	21

RT Persei

Nov.	1	4
	2	1
	2	21
	3	17
	4	14
	5	10
	6	7
	7	3
	7	23
	8	20
	9	16
	10	13
	11	9
	12	5
	13	2
	14	19
	15	15
	16	11
	17	8
	18	4
	19	0

RT Persei

Nov.	19	21
	20	17
	21	14
	22	10
	23	6
	24	3
	24	23
	25	20
	26	16
	27	12
	28	9
	29	5
	30	1
	30	22

λ Tauri

Nov.	1	22
	5	21
	9	20
	13	18
	17	17
	21	16
	25	15
	29	14

RW Tauri

Nov.	2	8
	5	2
	7	21
	10	15
	13	10
	16	4
	18	23
	21	17
	24	12
	27	6
	30	1

RW Persei

Nov.	13	0
	26	5

RS Cephei

Nov.	6	16
	19	3

RW Geminorum

Nov.	1	11
	4	7
	7	4
	10	1
	12	22
	15	18
	18	15
	21	12
	24	9
	27	5
	30	2

R Canis Maj.

Nov.	1	0
	2	4
	3	7
	4	10

R Canis Maj.

Nov.	5	14
	6	17
	7	20
	8	23
	10	3
	11	6
	12	9
	13	12
	14	16
	15	19
	16	22
	18	1
	19	5
	20	8
	21	11
	22	15
	23	18
	24	21
	26	0
	27	4
	28	7
	29	10
	30	13

Y Camelopardi

Nov.	3	6
	6	13
	9	20
	13	4
	16	11
	19	18
	23	2
	26	9

RR Puppis

Nov.	3	3
	9	13
	16	0
	22	10
	28	20

V Puppis

Nov.	2	4
	3	15
	5	2
	6	13
	8	0
	9	11
	10	21
	12	8
	13	19
	15	6
	16	17
	18	4
	19	15
	21	2
	22	13
	24	0
	25	11
	26	21
	28	7
	29	19

X Carinæ

	d	h
Nov.	1	11
	2	12
	3	14
	4	16
	5	18
	6	20
	7	22
	9	0
	10	2
	11	4
	12	6
	13	8
	14	10
	15	12
	16	14
	17	16
	18	18
	19	20
	20	22
	22	0
	23	2
	24	4
	25	6
	26	8
	27	10
	28	12
	29	14
	30	16

S Cancri

Nov.	3	4
	12	16
	22	4

S Velorum

Nov.	1	3
	7	2
	13	0
	18	23
	24	21
	30	19

RR Velorum

Nov.	2	20
	4	16
	6	13
	8	9
	10	6
	12	2
	13	23
	15	19
	17	16
	19	12
	21	9
	23	5
	25	2
	26	22
	28	19
	30	15

SS Carinae

	d	h
Nov.	3	14
	6	22
	10	5
	13	12
	16	19
	20	3
	23	10
	26	17
	30	0

Z Draconis

Nov.	2	8
	3	17
	5	1
	6	10
	7	19
	9	3
	10	12
	11	20
	13	5
	14	13
	15	22
	17	7
	18	15
	20	0
	21	8
	22	17
	24	2
	25	10
	26	19
	28	3
	29	12
	30	20

Z Herculis

Nov.	1	16
	3	13
	5	16
	7	13
	9	15
	11	12
	13	15
	15	12
	17	15
	19	12
	21	15
	23	12
	25	15
	27	12
	29	15

RS Sagittarii

Nov.	3	6
	5	16
	8	2
	10	12
	12	22
	15	8
	17	18
	20	4
	22	14

Minima of Variable Stars of the Algol Type.—Continued.

RS Sagittarii

	d	h
Nov.	25	0
	27	10
	30	20

V Serpentis

Nov.	3	12
	6	23
	10	10
	13	21
	17	8
	20	19
	29	6
	27	17

RX Herculis

Nov.	1	19
	2	16
	3	14
	4	11
	5	8
	6	6
	7	3
	8	0
	8	22
	9	19
	10	17
	11	14
	12	11
	13	9
	14	6
	15	3
	16	1
	16	22
	17	19
	18	17
	19	14
	20	11
	21	9
	22	6
	23	3
	24	1
	24	22
	25	20
	26	17
	27	14
	28	11

RX Herculis

	d	h
Nov.	29	9
	30	6

SX Sagittarii

Nov.	2	0
	4	2
	6	3
	8	5
	10	7
	12	9
	14	11
	16	13
	18	14
	20	16
	22	18
	24	20
	26	22
	29	0

RR Draconis

Nov.	1	16
	4	12
	7	8
	10	4
	13	0
	15	20
	18	16
	21	12
	24	8
	27	4
	30	0

RV Lyræ

Nov.	2	9
	6	0
	9	14
	13	4
	16	19
	20	9
	23	23
	27	14

U Sagittæ

Nov.	4	8
	7	17
	11	2
	14	11

U Sagittæ

	d	h
Nov.	17	20
	21	6
	24	15
	28	0

SY Cygni

Nov.	2	2
	8	2
	14	3
	20	3
	26	3

WW Cygni

Nov.	3	20
	7	3
	10	11
	13	19
	17	2
	20	10
	23	18
	27	1
	30	9

SW Cygni

Nov.	2	22
	7	12
	12	1
	16	15
	21	5
	25	19
	30	8

VW Cygni

Nov.	2	23
	11	10
	19	20
	28	6

UW Cygni

Nov.	1	21
	5	8
	8	19
	12	6
	15	17
	19	4
	22	14
	26	1
	29	12

W Delphini

	d	h
Nov.	5	8
	10	4
	14	23
	19	18
	14	14
	29	9

RR Delphini

Nov.	4	15
	9	6
	13	20
	18	10
	23	1
	27	15

RV Capricorni

Nov.	3	6
	6	12
	9	19
	12	1
	15	7
	18	13
	21	19
	25	1
	28	7

VV Cygni

Nov.	2	2
	3	13
	5	1
	6	12
	8	0
	9	11
	10	22
	12	11
	13	21
	15	9
	16	20
	18	8
	19	19
	21	7
	22	18
	24	5
	25	17
	27	4
	28	16
	30	3

UZ Cygni

	d	h
Nov.	8	15

RZ Cassiop.

Nov.	1	5
	2	10
	3	15
	4	19
	6	0
	7	5
	8	10
	9	14
	10	19
	12	0
	13	4
	14	9
	15	14
	16	18
	17	23
	19	33
	20	8
	21	13
	22	18
	23	22
	25	3
	26	8
	27	12
	28	17
	29	22

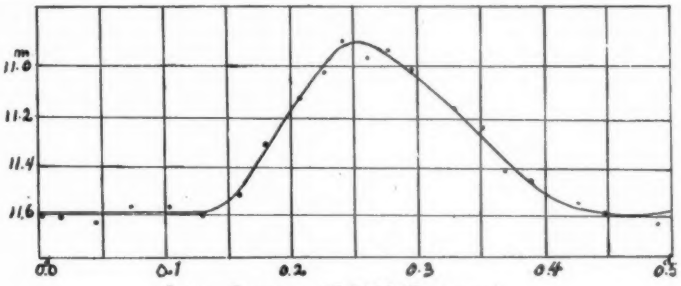
24.1907 Monoc.

Nov.	2	19
	4	16
	6	14
	8	12
	10	10
	12	8
	14	5
	16	3
	18	1
	19	23
	21	20
	23	18
	25	16
	27	14
	29	11

Period and Light Curve of the Variable 87.1906 Draconis.—In *A.N.* 4194 Mr. Naozo Ichinohe of the Yerkes Observatory gives results of observations of this variable, which indicate that its period is only $10^h\ 37^m\ 35^s$ and that the range of variation is from $10^m.9$ to $11^m.6$. The elements are:

$$\text{Max.} = 2417560^d.134 + 0^d.4428\ E$$
$$= 1906\ \text{Dec.}\ 15\ 3^h\ 12^m\ 58^s + 10^h\ 37^m\ 35^s\ E.$$

The light curve is like that of the "cluster" type rising rapidly before maximum, descending more slowly and remaining at minimum for quite a portion of the period. The variable is near the seventh magnitude star BD 58° 1650, pre-



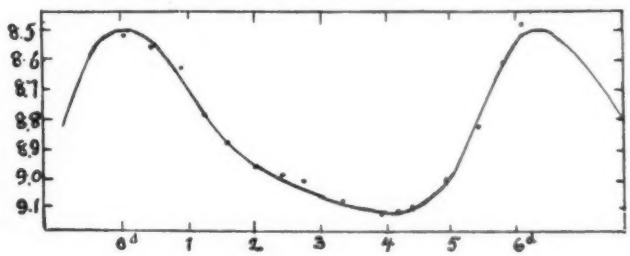
LIGHT CURVE OF 87.1906 (DRACONIS).

ceding it in R.A. by 8ˢ.44 and north 3′ 31″. The positions for 1900 of the variable and three faint comparison stars are as follows:

star	R. A.			Dec.			Mag.
	h	m	s	°	′	″	
c	16	33	10.55	+58	02	25.3	11.5
a	16	33	31.93	+58	02	46.1	10.7
v	16	33	43.26	+58	02	35.8	
A	16	33	51.70	+57	59	04.4	7.1
b	16	34	04.68	+57	57	17.2	11.34

Elements and Light Curve of X Vulpeculæ.—In *A.N.* 4195 Mr. M. Luizet of Lyon, France, gives new elements of this variable star depending upon his own observations extending from June 6, 1906 to January 12, 1907, and those of Messrs. Seares and Haynes of the Laws Observatory in 1905 and 1906. The new elements are

Max. = 2417040.738 (Paris m. t.) + $6^d.31896$ E
or 1905 July 13, $17^h\ 43^m$ (Paris m.t. + $6^d\ 7^h\ 39^m\ 18^s$ E.



LIGHT CURVE OF X VULPECULÆ.

The light curve shows that variable is of the δ Cephei type, the increase of light occupying 2.05 days while the decrease requires 4.27 days. The range of brightness is from $9^m.1$ to $8^m.5$.

Mr. Luizet used the following comparison stars:

			Mag.
A	BD	26° 3725	8.2
a	"	26 3739	8.7
b	"	26 3746	9.4
c	"	anonymous	9.7

The position of X Vulpeculæ is for 1900.0

R.A. = $19^h\ 53^m\ 19^s$ Dec. = + 26° 17′.3.

Elements of Certain Variable Stars.—In *A. N.* 4196 Mr. S. Blažko of the Moscow Observatory gives the following elements of a number of short period variable stars determined from his own observations:

		Julian Day Greenwich m. t.		Period. d	
RV Persei	Min.	2417301.3508	+	1.973525	E Algol type.
RU Monocerotis	Min.	2417261.3507	+	0.896153	E Algol type.
2.1907 Camelop.	Max.	2417620.0	+	22.27	E
87.1906 Draconis	Max.	2417560.134	−	0.44293	$E+0^h.55 \sin 2\pi\left(\frac{E-19.4}{94}\right)$.
26.1907 Draconis	Min.	2417674.348	+	0.55088	E Algol type.
U Scuti	Min.	2416358.3014	+	0.954977	E Algol tppe.
WW Cygni	Min.	2417462.3785	+	3.317708	E Algol type.
23.1907 Lacertæ	Max.	2417615.86	+	4.315	E δ Cephei type.
RS Cassiop.	Max.	2417263.2	+	4.985	E
RY Cassiop.	Max.	2417354.4	+	12.1435	E

The positions of these stars for 1900.0 and their ranges of magnitude are as follows:

	R. A. h	m	s	Dec. °	′	Mag.
RV Persei	4	04	09	+ 33	59.4	10.0—12.0
RU Monocerotis	6	49	24	− 7	28.2	9.8—10.5
2.1907 Camelop.	7	10	54	+ 69	51.2	8.0— 9.1
87.1906 Draconis	16	33	42	+ 58	02.6	9.9—11.0
26.1907 Draconis	18	21	49	+ 58	50.1	9.7—10.4
U Scuti	18	48	52	− 12	43.8	9.0— 9.8
WW Cygni	20	00	36	+ 41	18.4	9.5—12.5
23.1907 Lacertæ	22	05	13	+ 50	33.3	8.6— 9.2
RS Cassiop.	23	32	34	+ 61	52.5	9.1—10.0
RY Cassiop.	23	47	10	+ 58	11.2	9.2—10.0

Variable Star Notes.

V Boötis.

The period of this star is about 256 days though like many other variables, its light changes do not recur with marked punctuality.

The comparison stars used in noting the last maximum are those on the chart in POPULAR ASTRONOMY for October 1906, page 503. It rises to 7 magnitude at maximum.

1907, March 13 The variable equals c.
March 30 The same. Rising full Moon.
April 3, 7. The same. The seeing may be classed as 5 or middling.
April 15 It seems equal to a. Seeing poor.
April 17, 28, Equal to a. Seeing middling.
May 2 The same. Seeing middling.
May 7, 13. Two steps brighter than a. Seeing middling.
May 22 Equal to a. Gibbous Moon.

V Coronæ.

The last maximum of this variable occurred between March 13 and May 1. The comparison stars used in the following observations are those lettered on the chart in POPULAR ASTRONOMY August and September 1904, page 496. Its period is about 356 days.

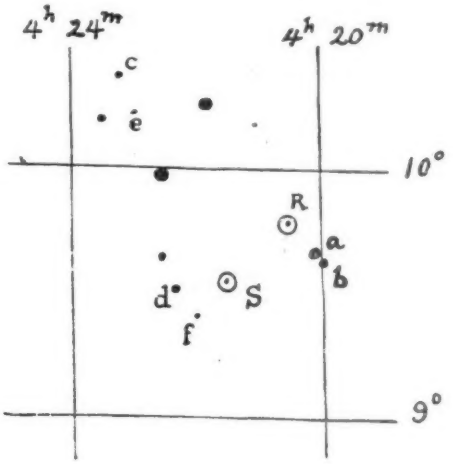
1906, December 12, The variable is midway between the luster of the two faint stars f and g. The morning is very clear.
1907, January 18. Between d and c.
March 13. Distinctly brighter than b or than c.

1907, April 3, 7, 11, 15, 16, 17, 22. There is no noticeable change.
May 2, 7, Equals b, brighter than c.
May 13 Between b and c.
May 22 Equal to c, less than b. Gibbous Moon.
June 8, 9 Less than c, equals d, brighter than f.

R TAURI.

Even without the aid of circles the neighborhood of this variable may be identified about five degrees south of the wide double star Theta in the Hyades. At maxima, the range may be from 9.2 to 7.4, and at minima from 12.4 to 13.5. The period is about 325 days. A maximum in December 1904, and intermediate phases during the succeeding years were observed as follows:

1904, October 30. Equal to e, less than c.
November 4, 8. The same.
November 27, 30 Equals b, less than a.
December 2, Equals a. Brighter than b. Night very clear.
December 6 Less than a. About midway between a and b.



VICINITY OF R AND S TAURI.

December 13, 16 Nearer to the brightness of b than of a.
December 24, Equal to b, less than a.
December 25, 31. Slightly less than b but nearer to b than to c.
1905, January 1, 2. About midway between b and c.
January 9 Equal to c.
January 24 Between the brightness of e and g.
February 2, 7, 9, 21. Equal to g.
March 3, Less than g. Brighter than h.
November 24, 29. Between e and g.
December 2. The same.
December 3. Equals g.
December 19, 31. Less than g. Equals h. Brighter than k, 31st very clear.

1906, January 20. Invisible. Night not very clear.
January 23. Of 11.5 magnitude. Less than k.
January 29. Invisible, k visible.
November 4, 9 Invisible.
December 12 Invisible.
1907, January 8, 14 Invisible.

S TAURI.

Being in the same field of view as R Tauri, S Tauri was also looked for on all the above dates, but was indiscernible with a few exceptions as below:
1904, December 2 Scarcely of 12 magnitude. Night very clear.
December 6 The same.
1905, February 21 Equals the adjacent star f.
March 3 Less than f or d. Equals m.
1906, November 4, 9 Of 11.5 magnitude. The range at maximum may be from 9.3 to 10 and at minima is below 13 magnitude. It has the rather long period of 375 days.

ROSE O'HALLORAN.

San Francisco,
Sept. 3, 1907.

GENERAL NOTES.

The Genesis of a Modern Lens. Ludwig Bunger has published in the "Zeitung für Optik" an extended article on the genesis of a modern lens. It gives a clear idea of the stages through which a modern high-class lens passes from the glass-works to the camera and to other optical instruments as well. This article is given in popular language, and it is therefore deserving of the attention of those who construct their own optical tools, as well as that of those who are professionally trained in fine glass-making and modern glass-working.

The Warner and Swasey Company. The name of this great company of manufacturers of Cleveland, Ohio, is sufficient for most of our readers to signify who they are and something of what they do.

Recently we had the pleasure of visiting the new workshops of this company, and of spending two most delightful days as the guest of Mr. W. R. Warner at his own elegant home on Euclid Avenue, Cleveland. Mr. Ambrose Swasey was in the East during the time, and so the opportunity of seeing him was regretfully missed. For a considerable portion of the summer he has been East and at Jamestown as Vice-President of the Exposition.

In passing leisurely through the new workshop, we were amazed to see the extent of the plant and the volume of work it is doing. Later we will speak more fully of the kind of work the company is doing, including the astronomical and the wonderful facilities they have created for carrying it on.

Urania in Lake Muskoka. Among the privileges that have come to us rarely in late years is that of seeing J. A. Brashear, one of the best, if not the leading optician in the United States.

While at Cleveland an opportunity came for us to go to Lake Muskoka which is about 130 miles north and west of the city of Toronto in Canada.

Some of our readers know that Lake Muskoka with others near it is now a famous resort for people of Philadelphia and other eastern cities, because of the many surprisingly beautiful, wooded islands of all sizes scattered everywhere through all these large lakes.

Urania is the name of one of these lovely islands which is owned by Mr. Brashear. It is only one-half mile into Lake Muskoka from the town of Beaumaris which is on a larger island in the same lake. Mr. Brashear has built him a commodious summer home on Urania, a shop and two landings. He is the owner of a fine steam launch which is the source of pleasure and delight to himself, his family and his numerous friends. As one of the last named class, we can testify to this very heartily, for during two days and more we saw much of Lakes Muskoka, Rosseau and George in company with Mr. and Mrs. Brashear and some of their friends.

We had some business in astronomical lines that made part of the object of this visit. When this is a little further advanced we will speak of it and Mr. Brashear's extensive work on large telescopes that is now going on at his shops in Allegheny City, Pennsylvania.

The Comet and the Chinese. The following interesting paragraph is taken from the Cleveland *Plain-Dealer* September 3, 1907.

Just what connection there is between the so-called sunspots and our earthly sphere the wise men fail to enlighten us. There are alarmists ready to ascribe various baleful influences to these mysterious spots. There was a time, too, when the approach of a comet presaged certain direful happenings. But there was more of superstition than science in all these predictions and warnings. Naturally we need not be surprised to learn that the present comet is greatly worrying the impressionable people of China. To the masses of the ignorant it is a flaming and malignant demon. Among these people a comet presages revolution, and a serious and regrettable phase of the matter is that in certain provinces the feeling among the natives is ripe for insurrection. Consequently, the celestial wanderer bids fair to become more of an excuse than a portent.

For ages without number the comet tribe has been a source of worry for the earthly watchers. On many occasions it was supposed our sphere lay directly in the pathway of the flaming visitor and that the Earth was doomed to a frightful fate. Of later years this terror has for the most part passed away, but it need not be considered surprising that there are sections of the Earth where the fiery mystery still inspires both awe and fright.

The Boyden Premium of $1000 about Light Rays and Physical Rays. Probably comparatively few of our readers remember if they ever knew that Uria A. Boyden of Boston, Mass., in 1859, deposited with the Franklin Institute the sum of $1000, to be awarded as a premium to "Any resident of North America who shall determine by experiment whether all rays of light, and other physical rays, are or are not translated with the same velocity."

The more specific definition of the problem as given by the Board of Managers is as follows:—

"Whether or not all rays in the spectrum known at the time the offer was made, (March 23, 1859), and comprised between the lowest frequency known thermal rays in the infra-red and the highest frequency known rays in the ultra-violet, which in the opinion of the Committee lie between the approximate fre-

quency of 2×10^{14} double vibrations per second in the infra-red and 8×10^{14} in the ultra-violet, travel through free space with the same velocity."

At a meeting of the Franklin Institute in June last a paper was presented by Dr. Paul A. Heyl, "On the Speed of the Invisible Portions of the Spectrum."

Venus as a Luminous Ring. The observation of this rare phase of *Venus*, made by one of us in 1898;* was repeated by the other at the conjunction of 1906, the observer's notes being as follows:

"On 1906 November 29, $5^h\ 7^m$ G. M. T., *Venus*, about $1°\ 49'$ from the Sun's center, was observed with the 5-inch finder of the 23-inch telescope. In moments when the air was steady the complete outline of the planet was distinctly seen. On the side nearest the Sun it was bright and easily visible, but on the opposite it was very faint and could be seen only for a few seconds at a time.

When the complete circle was seen, the space within it always seemed a shade darker than without. I suspect, however, that this was a subjective effect, as it was not noticed when the fainter part of the ring disappeared through bad seeing. No other marked peculiarities were noticed though a bright spot was several times suspected in the bright part of the ring.

The sky was very clear and blue. There was a strong wind from the northwest. The seeing was generally poor, but at times it was fair and steady for a few seconds. The whiteness of the field varied noticeably from time to time."

The planet was also observed on November 27 and December 4, and the extent of the crescent measured with a filar micrometer. Bad weather prevented further observations.

Reducing the results by the formulae of the paper already referred to, we obtain the following values for the extent of the twilight arc in the atmosphere of *Venus*.

Date 1906	Observer	Seeing	Apparent Elongation of Venus from Sun v	Prolongation of Each Cusp p	Twilight Arc s
Nov. 27.....	H. N. R.	Poor	$4°\ 33'$	$20°$	$58'$
Nov. 29.....	Z. D.	Fair	$1\ \ 49$	90	>62
Dec. 4.....	H. N. R.	Very bad	$7\ \ 14$	10.4	45

The last value is clearly too small, owing no doubt to the very bad seeing, which would render the delicate extremities of the cusps invisible. The other values agree fairly well with the mean value $70'$ found in the earlier discussion.

* H. N. Russell, *Astrophysical Journal*, 9, 284, 1899.

The ring-phase of *Venus* may perhaps be seen again in 1914, if the atmospheric conditions are very favorable. There will be no other opportunity until 1972.

HENRY NORRIS RUSSELL.
ZACCHEUS DANIEL.

Princeton University Observatory,
June 3, 1907.

Auroral Display. Referring to Messrs. Harvey's and Campbell's articles on Auroral Arches and Northern Lights appearing in No. 147 of your paper, I beg to advise you that this same phenomenon was observed by me on September 2nd, 1906 in the Sabinas Coal Fields.

From the setting Sun four streaks of bright light diverged towards the zenith, where they reached a maximum width of about 3°, and they converged

to the opposite side of the hoirzon to a point just where the full Moon was rising at that moment. This is the most beautiful phenomenon of the kind I ever saw. I do not remember the color of these beams of light, nor how long they were visible, but I saw them for over half an hour.

A. G. Zambrano.

Monterrey, Mexico.

Henry O. Severance, Librarian of the University of Missouri sends in the following list of astronomical publications of this country. If there are omitted any which should be included in this list, it will be a favor if such data are sent in to make complete if possible Mr. Severance's list.

ASTRONOMY

Astronomical journal.
Astronomical society of the Pacific. Publications of
Astrophysical journal.
California University. Publications. Astronomy,
Bulletin.
Lick Observatory publications.
Cincinnati University Observatory. Publications.
Columbia University. Contributions from the observatory.
Detroit Observatory Transactions.
Goodsell Observatory. Popular Astronomy.
Publications.
Harvard University, Astronomical observatory. Annals,
Report of Director,
Report of H. Draper Memorial.
Illinois University, Astronomical observatory. Bulletin.
Laws Observatory, University of Missouri. Bulletin.
Leander McCormick Observatory of the University of Virginia, Publications.
Lowell Observatory Annals,
Bulletin.
Mars Weekly Planet.
Pennsylvania University. Publications,
Series in Astronomy.
Vassar College Observatory, Publications.
Yale University, Astronomical Observatory. Reports.
Transactions.
Yerkes Observatory. Publications.
United States Naval Observatory, Publications.

Meteor Observed. Having heard that reports on unusual phenomena, even when made by untrained observers, were of use to you, I take the liberty of reporting a meteor seen by me this evening.

At about 10:50 P. M., I saw an unusually large shooting star starting from the meridian and about 35° from the southern horizon with a nearly westerly course dropping to about 20°; the distance traveled would cover nearly 10°.

In apparent size it was larger than any of the planets and just before disappearing split into two distinct balls of fire which immediately vanished.

Wm. Sharpless.

Rome, N. Y.

The Distant Stars. If we think of the distances of the stars in miles, or in any other unit of measure with which we familiar, they are so appallingly great that no one can comprehend them. If α Centauri is the nearest fixed star, as

best we know its distance in miles is more than twenty-five millions of millions (25,246,000,000,000). If we say light travels 5,880,100,000,000 miles in a year which is approximately correct, then by dividing one of these numbers by the other, we find that it would require about 4.3 years for light to come to us from the nearest fixed star. These units are called light years.

In the same way the distance of

Sirius	is	8.6 light years.
Vega	is	21.7 " "
Fomalhaut	is	23.3 " "
Polaris	is	44.0 " "

In this way the measuring of these bewildering figures come into mind somewhat more fully.

Erratum. In the August-September number, page 448; for June 1, 1907 read June 17, 1907, in the title of the sunspot drawing given.

PUBLISHER'S NOTICES.

Contributors are asked to prepare copy carefully, and write *all proper names very plainly*. If other language than the English is used to any considerable extent it should be type-written. Manuscript to be returned should be accompanied by postage for that purpose.

All Drawings for publication should be done in India ink, twice the size that the cut will be on the printed page. The lines, figures and letters should be made even, very smooth and uniformly black in every part of the copy, in order to secure the best reproductions possible by the modern quick processes of engraving now most generally used.

Proofs will generally be sent to authors living in the United States, if copy is furnished before the first of the month preceding that of publication. We greatly prefer that authors should read their own proofs, and we will faithfully see that all corrections are made in the final proofs.

Renewals.—Notices of expiration of subscription are sent directly after the last number of this publication for which payment has been made. It is especially requested that subscribers will send renewal, or order for renewal, promptly as this publication will not be continued beyond the time for which it has been ordered.

Astronomical News.—It is very much desired on the part of the management, that brief news paragraphs of astronomical work in all the leading observatories of the United States be furnished to this publication, as regularly and as often as possible.

The work of amateur astronomers, and the mention of "personals" concerning prominent astronomers will be welcome at any time.

The building and equipping of new observatories, the manufacture, sale or purchase of new astronomical instruments, with special reference to improvements and new designs, and the results of new methods of work in popular language, will be deemed very important matter and will receive prompt attention. It is greatly desired that all persons interested bear us in mind and promptly respond to these requests.

Messrs. Wm. Wesley & Son, 28 Essex Street, Strand, London, England, are our sole European agents.

Reprints of articles for authors, when desired, will be furnished in titled paper covers at small cost. Persons wanting reprints should order them when the manuscript is sent to the publisher. They cannot be furnished later without incurring much greater expense.

Subscription Price Changed. Beginning with January 1906, the price of Popular Astronomy a volume, of ten numbers each, to subscribers living in the United States, its territory, and Mexico was changed to $3.50; the price to all others is $4.00; in each case payable strictly in advance.

Back volumes or single numbers issued previous to the change of price, January 1906, are still on sale at the old prices, $2.50 and 30 cents respectively.

WM. W. PAYNE,
Northfield, Minn., U. S. A.